NOVEMBER · 1940

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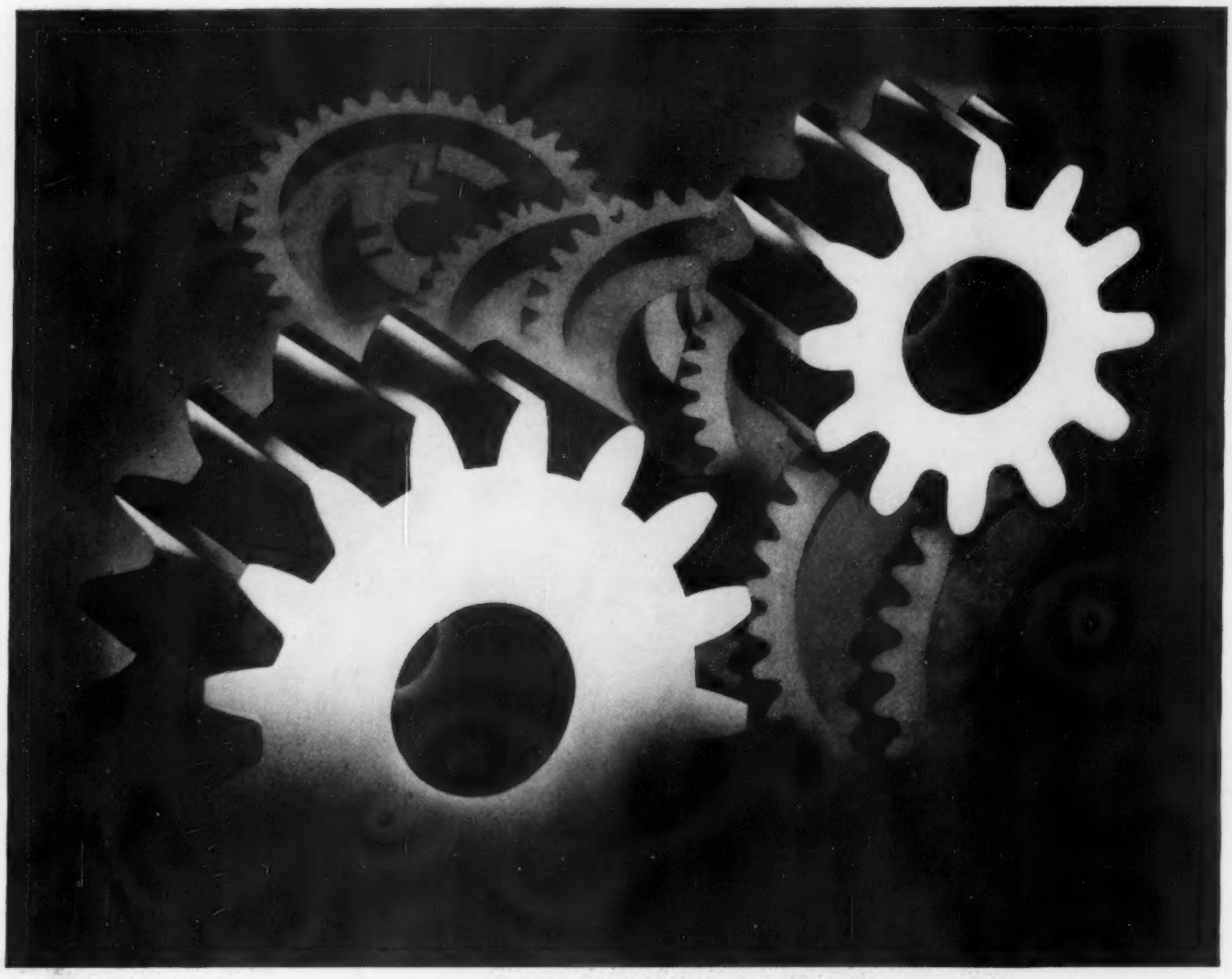
THE TECH ENGINEERING NEWS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY



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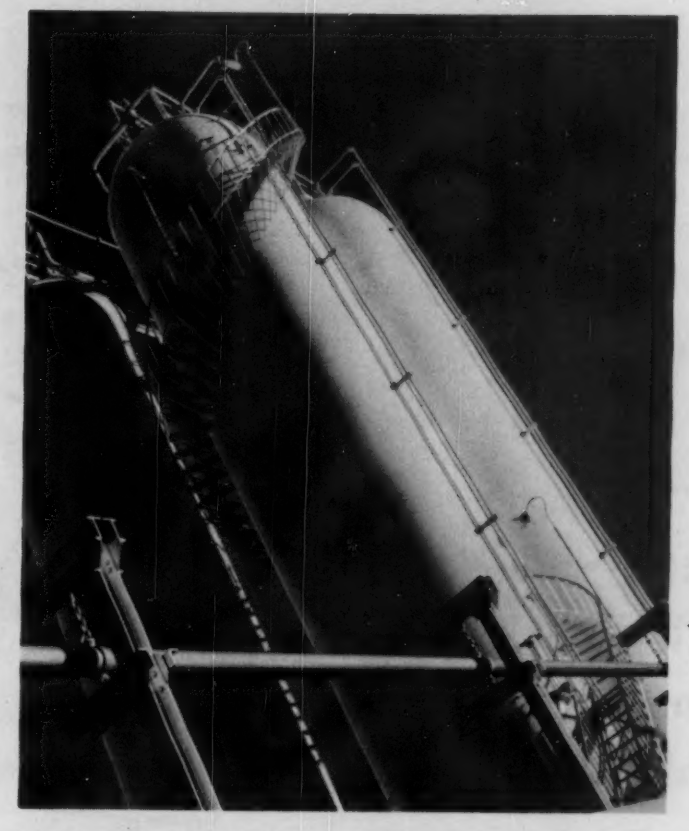

OUR COVER THIS MONTH

Shows a group of tanks for storing liquefied petroleum gas under pressure.

VOLUME XXI
NUMBER 6

• CONTENTS •

295 THE POLYFORM PETROLEUM PROCESS — DR. E. R. SMOLEY
Greater conversion per pass means higher octane gasoline and improved efficiency.

289 THE CHEMICAL ENGINEER — PROF. WALTER J. WHITMAN
Whether peace or war comes, there is an expanding future in the chemical industry.

291 SYNTHETIC RUBBERS — DR. PER K. FROHLICH
Like silk, natural rubber may soon be largely replaced by man-made substitutes.

286 MOLDED AIRPLANES FOR DEFENSE
Abridged reprint from "Modern Plastics" for July, 1940.

283 THE CHEMICAL ENGINEER'S PART IN PREPAREDNESS — S. D. KIRKPATRICK
Immediate expansion of munitions and synthetic rubber plants calls for more technical men.

297 PRODUCING GLASS — DR. F. W. ADAMS
From sand to "Coke" bottles, the chemical engineer plays an important part.

281 OUR AUTHORS

MEMBER OF THE ENGINEERING COLLEGE MAGAZINES ASSOCIATED

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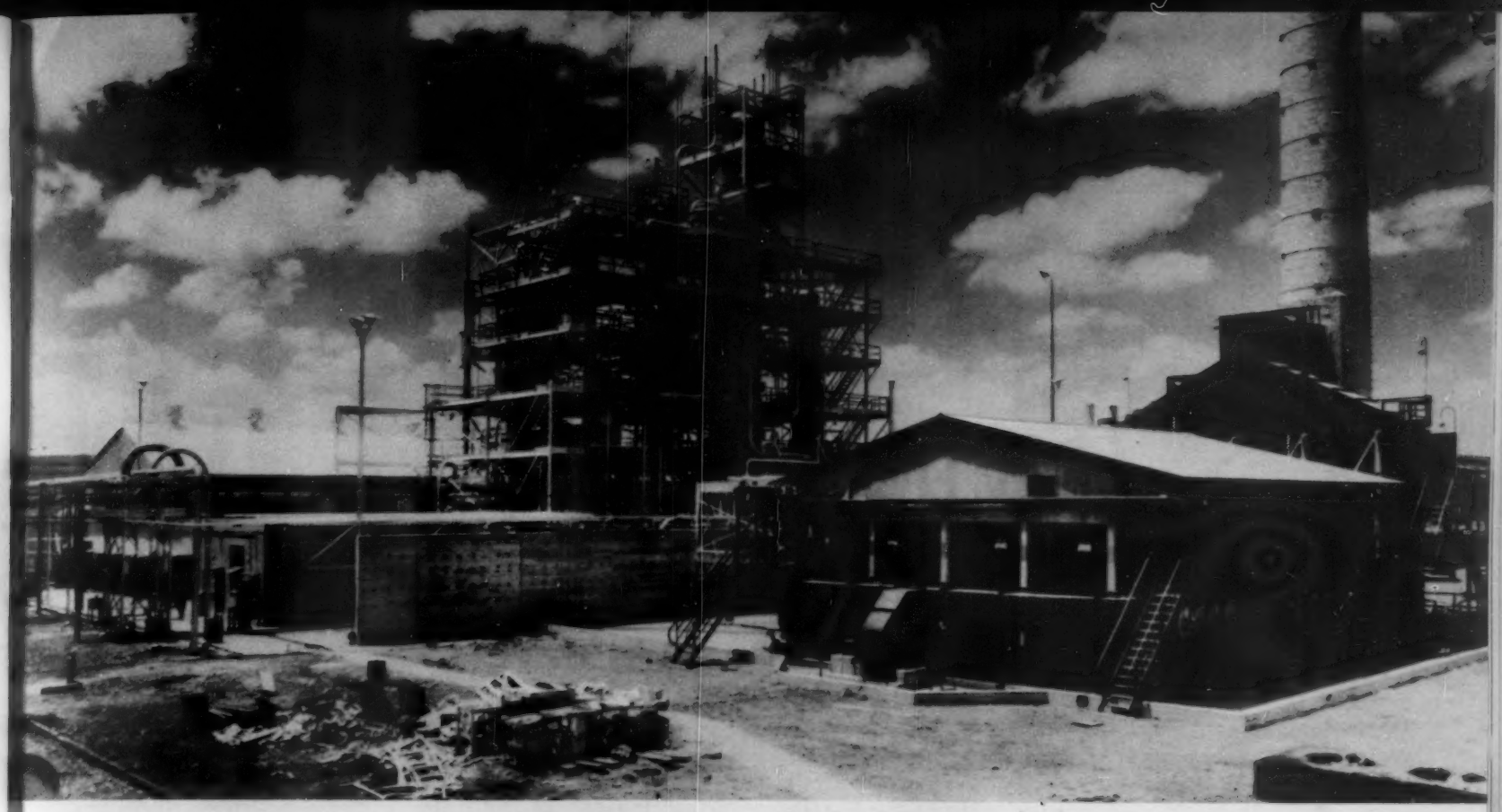


OUR AUTHORS

PROFESSOR W. G. WHITMAN, head of the department of chemical engineering at Technology, is the author of "The Chemical Engineer." He began teaching at the Institute in 1917, rising to the position of assistant director of the research laboratory in Applied Chemistry by 1925. At this time Professor Whitman left the Institute to work as assistant director and later associate director of research for the Standard Oil Co. of Indiana. In 1934 he returned to the Institute to head the department of chemical engineering and become director of the school of engineering practice. Obviously, Professor Whitman knows where the better opportunities are in the chemical engineering field, and he mentions them in his article.

MR. S. D. KIRKPATRICK has long been in contact with the chemical industry. In 1917 he became an editor for McGraw-Hill Publishing Co. Later he was made director of chemical engineering texts and reference books. In 1921 he became assistant editor of *The Chemical and Metallurgical Engineering* and rose to his present position of editor-in-chief in 1928. He has also served on special government commissions to Europe, and for short periods with private industry. Presently working with a government committee, his broad knowledge and experience in the chemical industry place him in an authoritative position for writing on the industry's part in preparedness.

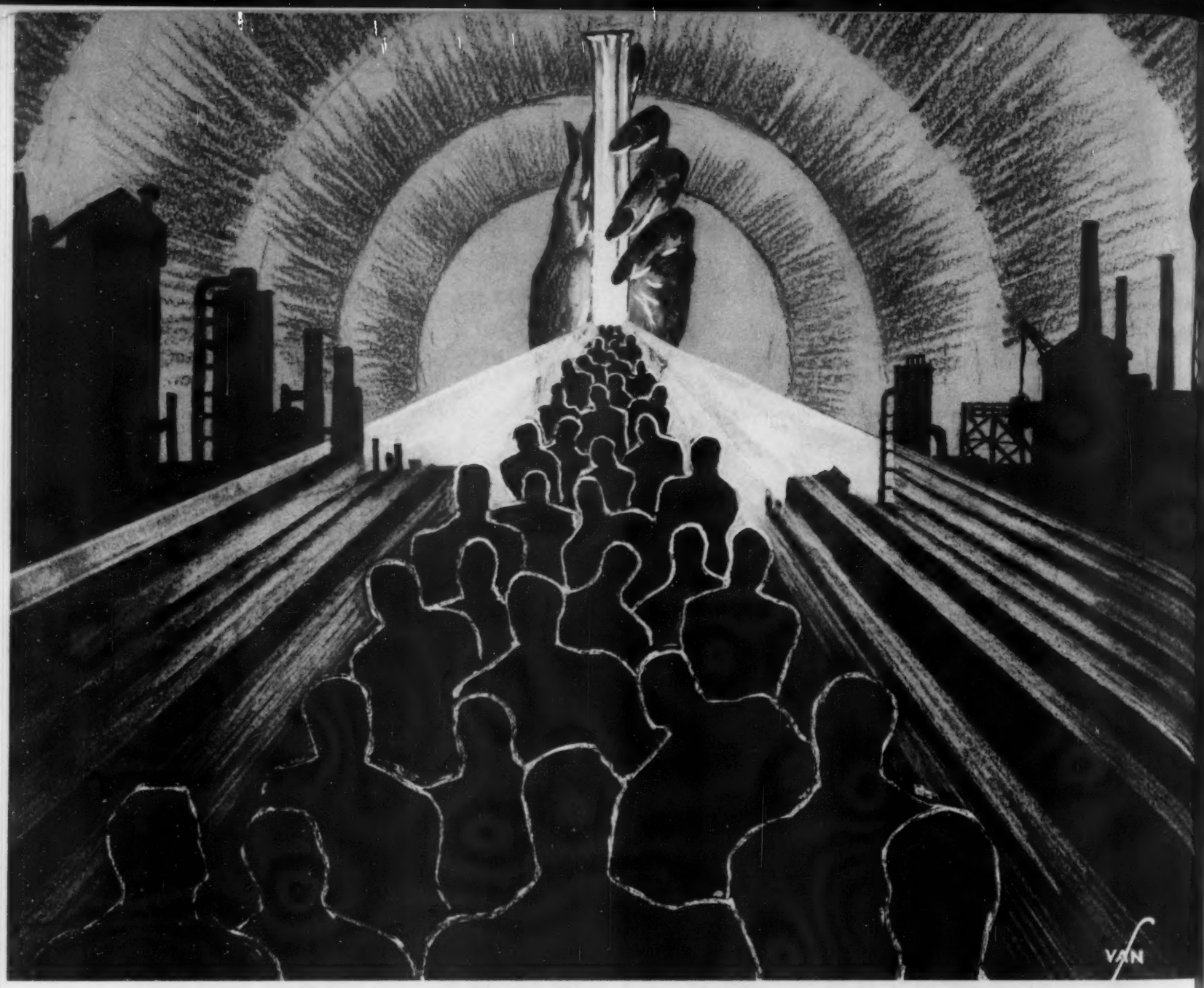
DR. E. R. SMOLEY, author of "The Polyform Petroleum Process," graduated from Technology in 1919 and received his Doctor's degree in 1930. From 1920 to 1928 he worked for the New Jersey Zinc Co., and The Aluminum Co. of America. He then returned to the Institute as a member of the staff for the next two years. From 1933 to 1934 he was a chemical engineer for the M. K. Kellogg Co.

Dr. Smoley branched into sales engineering in 1934 when he joined The Lummus Co., where he has continued to date. He is an authority on rectification of heavy naphthas, production of lubricating oils, and combination selective cracking.

DR. F. W. ADAMS, a graduate of the class of 1921 at Technology, is now a senior industrial fellow of the Mellon Institute at Pittsburgh. From 1922 to 1936 he was on the Institute staff in the chemical engineering department, becoming assistant professor in 1924. He received his Doctor's degree in 1928. While on the staff at the Institute he taught both in the Bangor field station of chemical engineering practice and the Boston field station. In 1936 he left the staff to take up his present position at the Mellon Institute. Dr. Adams, author of "Producing Glass," has specialized in paper drying and ventilating, heavy chemicals, glass and paint.

DR. PER K. FROHLICH, director of the chemical laboratories of the Standard Oil Development Co., and MR. J. R. BROWN, also at the Standard Oil Development Co., are the authors of the article on synthetic rubber. Since graduation from the Norway Institute of Technology, Dr. Frohlich has gained wide experience in chemical research. By 1925 he had received his B.S. and D.Sc. degree from the Massachusetts Institute of Technology, and was made a research assistant in their research laboratory of applied chemistry. In the next five years he rose to associate professor in chemical engineering at the Institute.

In 1931 he accepted a position with the Bayway Research Laboratories (now Esso Research Laboratories) as an assistant director, and was made director in charge of research two years later. Since 1936, however, he has held his present position with the Standard Oil Development Co.



THE CHEMICAL INDUSTRY

In a world torn with human strife and spreading war, the United States is once again caught near the zero hour. As a result of the foresight and resourcefulness of industry, we will not be entirely unprepared this time.

Notable among the industries now rapidly preparing for eventualities are those in the chemical field. Catapulted into large-scale development by the last war, the chemical industries over the past twenty-five years have expanded into other fields entirely divorced from explosives, and dedicated to the advancement of mankind. Now they are called upon to do a major part in making the defense powers of the United States unsurpassable.

Because of the fact that the chemical industries serve all other fields, the TECH ENGINEERING NEWS presents in this issue a group of articles pointing out recent developments and opportunities in several specific fields. Written by recognized chemical engineers, the articles cover a few prominent chemical industries including petroleum, synthetic rubbers, glass, and aviation plastics. An article on chemical engineering opportunities, and another discussing chemical national preparedness round out the issue.

THE CHEMICAL ENGINEER'S PART IN PREPAREDNESS

IMMEDIATE EXPANSION OF MUNITIONS AND SYNTHETIC RUBBER PLANTS CALLS FOR MORE TECHNICAL MEN

By SIDNEY D. KIRKPATRICK

EDITOR, CHEMICAL AND METALLURGICAL ENGINEERING

CHEMICAL engineering may or may not have had its birth during World War I, but certainly it got its baptism of fire in those strenuous days of 1917 and 1918. First the Allies and then our own government called on the infant American chemical industries to make the munitions that were vitally necessary to carry on the war in Europe. Within the 19 months from April, 1917, to November, 1918, more than 50 new plants were built for making explosives and propellants and for loading them into shells and ammunition. We spent a third of a billion dollars but we got results.

By November, 1918, American plants were producing at the rate of 42,775,000 lbs. per month of smokeless powder and 47,888,000 lbs. of high explosives. In the 19 months that we were in the World War we produced 632,504,000 lbs. of propellants, which was more than England and France produced together in four years. Then came the Armistice, followed a few years later by the pacifists' campaigns against the munitions makers. In a short while it became so unpopular to have anything to do with military explosives in this country that all the plants were completely dismantled and the equipment sold for junk.

Now we are being asked to start all over again. Smokeless powder and TNT become No. 1 priorities as the government begins to build back its military explosives business. Almost $300,000,000 has been appropriated for the construction of a chain of huge plants, most of which are to be government owned but operated on a fee basis by private companies.

To design and construct these plants in the shortest possible time is placing a heavy burden on the engineering departments of the larger chemical companies and on their contractors and subcontractors. When the plants are completed and ready for operation, there will undoubtedly be a tremendous demand for technically trained men for management and supervision as well as for inspection and control of production. Looking forward to the necessity for meeting these needs with trained men, the National Defense Advisory Commission has set up a special training unit under the direction of C. R. Dooley, an experienced personnel man from industry. The Federal Office of Education will also aid in providing special training of college grade for the personnel which is of more than artisan or operative level.

To make certain that the government does not overlook the availability of technical men in industry or now unemployed who are specially qualified for defense activities, Uncle Sam has embarked on the job of cataloging all the scientific and specialized brain power of the nation into a giant file. This is to be known as the National Roster of Scientific and Specialized Personnel and is sponsored by the National Resources Planning Board and the Civil Service Commission in coöperation with the various engineering and scientific societies of the country. Chemists and chemical engineers are being circularized with a comprehensive questionnaire from the American Chemical Society and an even more exhaustive one is in prospect from the American Institute of Chemical Engineers.

Thus the government is striving to avoid the personnel "bottlenecks" that might add to the delay in getting its munitions program under way during 1941. In the meantime there is an even more urgent drive to line up the necessary supplies of raw materials. To produce 330,000,000 lbs. of smokeless powder, 240,000,000 lbs. of high explosives, and 12,000,000 lbs. of black powder during the World War required the following raw materials:

234,300,000	lbs. of purified cotton linters
183,500,000	lbs. of alcohol
50,400,000	lbs. of toluol
9,000,000	lbs. of benzol
27,500,000	lbs. of ammonia
611,400,000	lbs. of nitric acid
1,210,000,000	lbs. of sulphuric acid

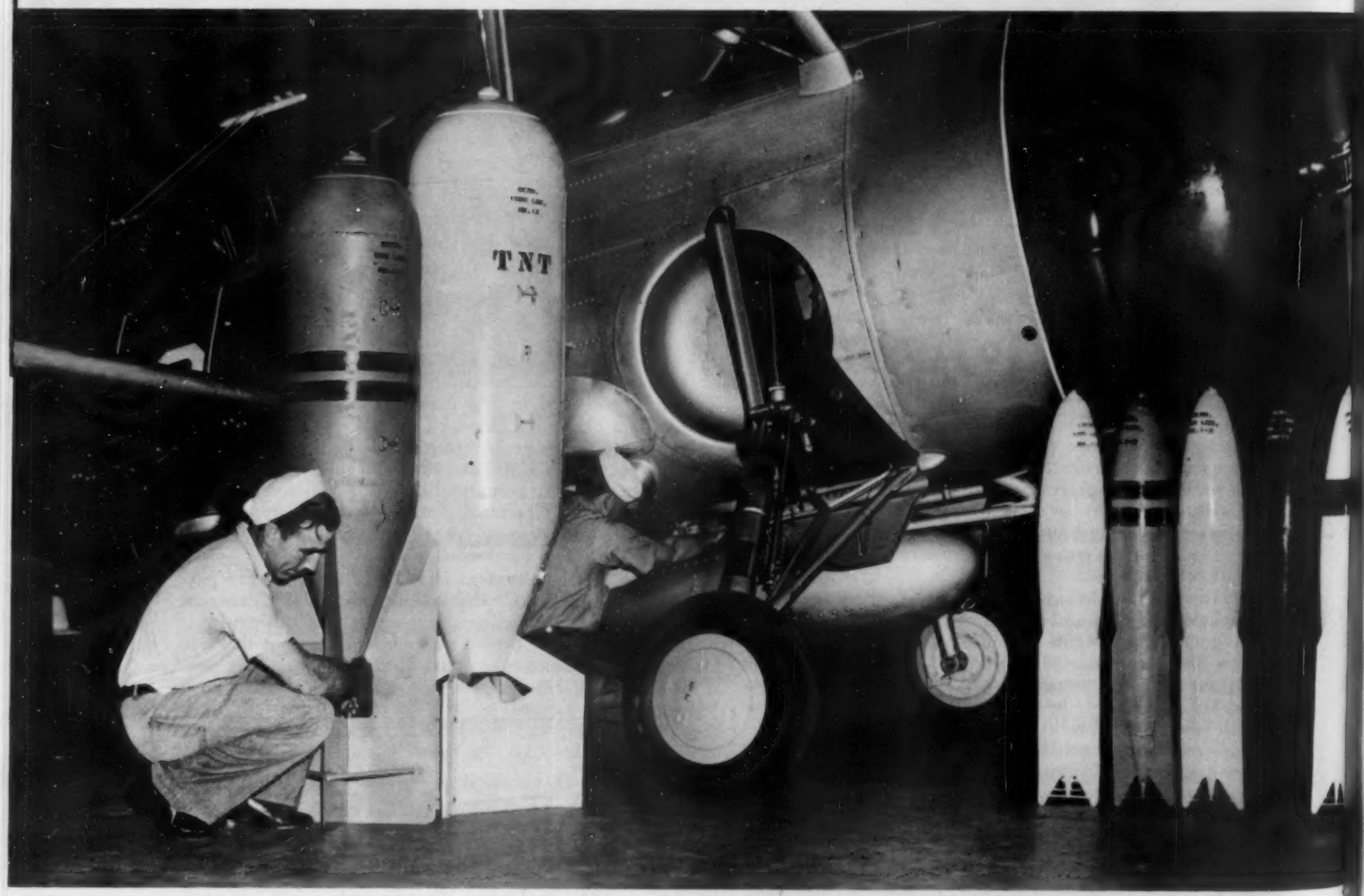
276,000 lbs. of mercury
9,000,000 lbs. of potassium nitrate
886,530,000 lbs. of sodium nitrate
425,000,000,000 lbs. of sulphur
1,300,000 lbs. of charcoal

Most important of these, of course, is nitrogen, reported here as sodium nitrate, nitric acid and ammonia. It will be noted from the previous table that the government munitions program contemplates the construction of two new synthetic ammonia plants at a cost of at least $30,000,000. When these are in operation they will probably add more than 100,000 tons to our present synthetic nitrogen capacity of about 300,000 tons. Even then, however, we fall far short of Germany's pre-war (September, 1939) nitrogen capacity of 1,365,850 metric tons. To this she has presumably added at least 500,000 tons from Norway, Belgium, Holland and France — so that today more than half of the world's synthetic nitrogen capacity is in German hands.

But this is not quite as serious a menace as it might seem because by-product ammonia from our coke ovens and, if necessary, increased imports of sodium nitrate from Chile, could quickly meet almost any conceivable need for either military or agricultural requirements.

Next to nitrogen in order of importance are sulphur and sulphuric acid — two products, in the manufacture of which we lead the world and for which our capacity could be quickly expanded. Toluol gave us some trouble in the last war when it was necessary to expand production from 700,000 lbs. per month in 1914 to 12,000,000 lbs. per month by November, 1918. Most of this was obtained from by-product coke ovens and by stripping from domestic heating and illuminating gas. We had barely begun to develop in 1918 what now appears to be our most promising source of supply, namely, the abundant hydrocarbons from petroleum. New synthetic processes have been developed by several of the larger oil companies whom the government has already contracted for supplies of nitration grade toluol. In one case (Humble Oil Refining Company of Baytown, Texas) the government is to finance the construction of the plant which will be operated by the refining company. The Shell Development Company, however, is building its own plant at Houston to produce 2,000,000 gals. per year and is ready to increase that output to 7,000,000 gals. when necessary.

Synthetic rubber holds a high place in the government's list of strategic and critical materials. As in the case of synthetic ammonia, however, we have the



"know-how" in this country and the nucleus on which we could build, if necessary, for our complete independence of foreign supply. Last year we produced only about 1,700 tons of synthetic rubber and consumed almost 600,000 tons of the natural product. This year the output of our synthetic plants will have jumped to at least 10,000 tons, but we are still a long way from the 200,000 tons per year that the Defense Commission estimates to be the minimum requirement in case imports are cut off or drastically curtailed. The big question of policy, therefore, is whether this country is warranted in embarking on a large expansion program for the construction of new plants, government owned or subsidized, or whether we should continue our present program of "normal" growth in the hands of private enterprise. Most engineers in the industry feel that the construction of any government-owned plants at this time might tend to freeze development in the industry for a good many years to come, but, of course, they would not oppose such a program in the hands of private industry should the emergency warrant.

Industrial Organization for Preparedness

The chemical industry is unusually well organized to contribute its share in the national defense program. Several years ago the Manufacturing Chemists' Association appointed a group of representative committees to coöperate with the Army and Navy Munitions Board in making a survey of the chemical needs of the military program. Lately that activity has been greatly expanded, and today approximately 20 committees are working closely with this Board and with the National Defense Advisory Commission. That these committees are truly representative of the industry as a whole, is evidenced by the fact that they include 120 men from 85 chemical companies whose annual sales are in excess of $300,000,000.

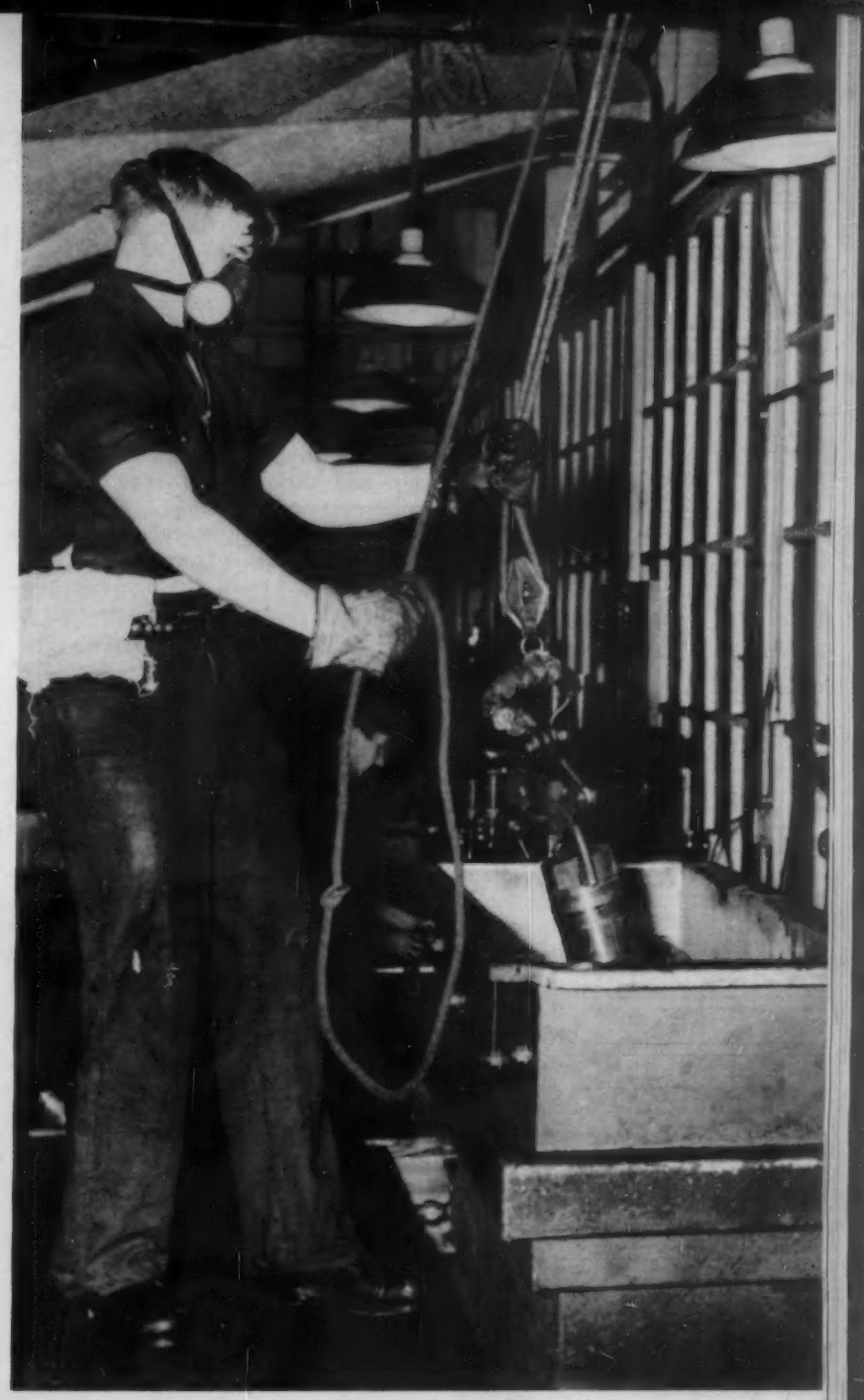
In the language of the National Defense Advisory Commission, chemicals are regarded primarily as raw materials. This means that they therefore come principally under the organization set up by Edward R. Stettinius, Jr., former chairman of the United States Steel Corporation. He has appointed as head of the major division on Chemical and Allied Products, Dr. Edward R. Weidlein, Director of Mellon Institute of Industrial Research and former president of both the American Chemical Society and the American Institute of Chemical Engineers. Weidlein has selected as group executive in charge of petroleum, natural gas and its products, Dr. Robert E. Wilson, President of Pan American Petroleum and Transport Company, and former professor of chemical engineering at Massachusetts Institute of Technology. He is assisted in this work by Dr. C. C. Monrad, associate professor of chemical engineering at Carnegie Institute of Technology.

Directly in charge of chemicals under Dr. Weidlein are two group executives, Dr. D. P. Morgan, chemical economist of Scudder, Stevens & Clark, investment counsellors of New York City, and Dr. E. W. Reid, senior research fellow for Carbide and Carbon Chemicals Corporation at the Mellon Institute.

One does not hear as much about chemical warfare these days, but it must be evident to all that the Chemical Warfare Service has a tremendous responsibility for the production of gas masks and other protective equipment. Appropriations in excess of $60,000,000 have been authorized to expand Edgewood Arsenal and to carry forward the program elsewhere.

Long before the present relationship between chemical industry and the Army and Navy Munitions Board had been consummated, the Chemical Warfare Service had set up its own procurement program. The entire country had been organized into five geographical districts, each with advisory boards made up of eight to fifteen leading industrialists. Educational orders have been placed for masks and vital chemicals needed in the C. W. S. program.

Thus it would seem that the chemical industry and chemical engineering carry heavy responsibilities in the nation's program to make this country safe from invasion and strong enough to defend itself against any foreign power or combination of powers. We hope these agencies of destruction will never have to be used. Chemical engineers, perhaps more than any other professional group, know that a better future lies in progress towards peace.



Passed by Canadian Censor.

Picture taken in a Canadian munitions factory shows shell casing being given an acid bath to remove greases, oils and other foreign matters before being sent into the test room, where it will be checked for measurements and weight.

MOLDED AIRPLANES FOR DEFENSE

(Abridged reprint courtesy of "Modern Plastics" for July, 1940)

FOUR aircraft companies and two major research institutions in the United States are today hard at work pushing the development of molded airplanes. The Army Air Corps and the Navy Bureau of Aeronautics, both close observers of the work, are authorizing laboratory tests on full-scale models. The two research organizations are increasing the available engineering data on the plastics and resins open to consideration for molded airplanes, to permit the selection of the best materials and methods of construction.

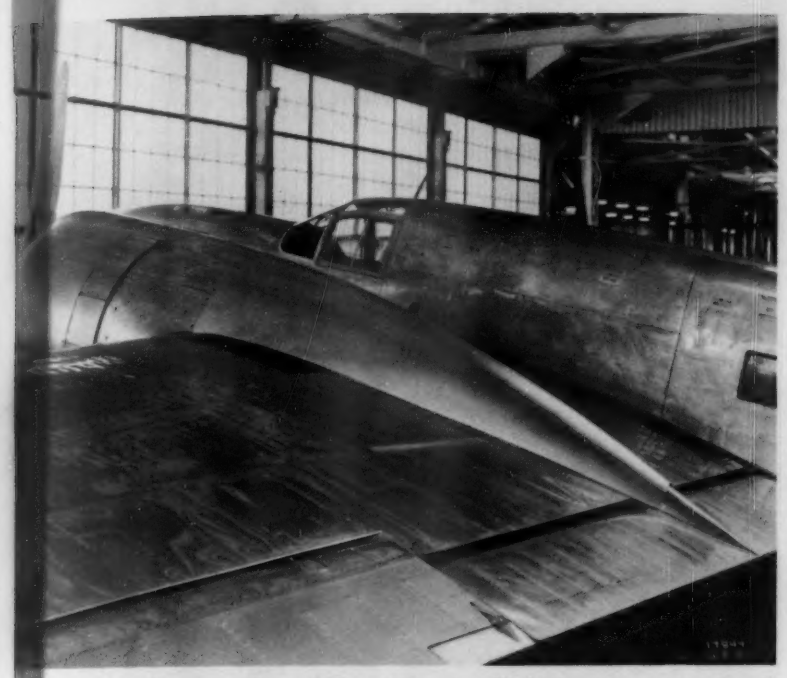
One of these research groups is working at the Mellon Institute under a fellowship established by the Glenn L. Martin Co. The most recent report concerning this work stated that "Advantages ascribed to the plastics form of construction include low cost of fabrication, high speed of production, good mechanical stability for a given weight, and excellent surface smoothness. The rapid molding of airplanes from plastics may ultimately supplant slower riveting and welding from metals, thereby facilitating mass production. Various plastics of the thermosetting fibrous-filler type have been prepared and tested, primary attention being given to materials of low specific gravity. An investigation of special molding methods is under way."[1]

The other research group is working in the Plastics Section of the National Bureau of Standards on a project sponsored by the National Advisory Committee for Aeronautics. The following summary of the work accomplished during 1939 is abstracted from the latest annual report of the N. A. C. A.[2] "Eighteen synthetic resins have been tested to determine their suitability for impregnating and bonding wood veneers to form a reinforced plastic of the requisite strength and stability for use in aircraft construction. Great differences were observed in the temperatures and pressures required for obtaining satisfactory bonds with these resins and in their degree of resistance to delaminating when alternately wetted and dried. On the basis of these data three of these resins have been selected for use as bonding and impregnating agents in the preparation of laboratory samples of reinforced plastics for strength tests. Tensile and compressive strength, modulus of elasticity, and water absorption have also been determined for a number of plastics which have been proposed by various commercial sources for use in building propellers, floats, spars, wings, and fuselages of airplanes. The reinforcing agents in these products included wood veneer, pressed wood, flax, jute, and sisal. The results

[1] Researches of the Mellon Institute 1939–40, News Edition of the American Chemical Society, *18*, 287–300 (April 10, 1940).

[2] Twenty-Fifth Annual Report of the National Advisory Committee for Aeronautics 1939. Available from the Superintendent of Documents, Government Printing Office, Washington, D. C , for 20 cents.

First all-molded airplane, "The Summit," was made by the "Vidal Process" with wings, fuselage, tail assembly and controls molded as complete structures in themselves. A flight test proved that the plane had a 137 mph top speed with only a 75 hp motor.



Rear portion of the engine cowling shown was produced by the Duramold Process. Note the comparative smoothness of the material and the absence of rivets and joints, which is desirable in airplane construction because of the resulting improved performance.

indicated that maximum strength and stiffness is attained with well-oriented fibers and thermosetting resins."

The publications of these research groups at the National Bureau of Standards and the Mellon Institute will fill a definite need for factual information on the physical properties of the reinforced plastics.

The four companies which have been more than merely interested in plastics as aircraft structural materials and have made a considerable investment in plant facilities for their production are Fairchild Engine and Airplane Corp., Hughes Aircraft Division of the Hughes Tool Co., Aircraft Research Corp., and the Timm Aircraft Co. All of these firms have utilized wood veneers as the fibrous reinforcing agent and have used synthetic resins of various types as the bonding and stabilizing agents. In each instance the plastic properties of the resins have been used to mold the body of the airplane and to set it in the desired shape. This is one of the essential differences between the plastic-plywood type of construction now used in molding airplanes and the old-time method of gluing the veneers together in a flat press, and then wetting or steaming the flat sheet and springing it into the requisite form. Mr. J. T. Hartson, vice-president of the Glenn L. Martin Co., says in a letter recently addressed to us, "It can be readily seen that this new process of forming the plywood relieves all internal strains, and the resulting product thereby remains stable and retains its shape during changes of atmospheric conditions. In the older type, where flat pressed plywood was steamed to compound curvature, there was always a tendency of the plywood to return to its original pressed condition and, therefore, the airplane changed shape, or wrinkled, with each change in atmospheric humidity and temperature." Of course, the new synthetic resin adhesives, which are proof against attack by molds, fungi, water, oil and gasoline, are also an essential element in the success of the new plastic-plywood structural material in the aircraft field.

Fairchild Engine and Airplane Corporation

Vance Breeze, well-known test pilot, over five years ago suggested to Sherman Fairchild, President of Fairchild Engine and Airplane Corp., the possibilities of a plastic-plywood airplane. He pointed out how through readily molded streamlined shapes and forms, with overall exterior sheen smoothness, aerodynamic drag could be minimized and a cheap simple structure developed to reduce the cost of airplane manufacture.

Concurrently, Colonel V. E. Clark, commissioned by Mr. Fairchild to find better and cheaper materials and processes for plane construction, had set out to investigate various rivetless possibilities. His search brought him to the front door of plastic-plywood. This material was not entirely new to Clark as he had built wood and glue monocoque fuselages during the last war. He had always been enthusiastic about the possibilities of wood except for the limitations of the then available glues. Here their efforts did not end. The horizons beyond were carefully explored — all the known factual data were assembled, preliminary laboratory tests were made, and a course for action was charted. Working with the Haskelite Manufacturing Corp., the Duramold Aircraft Corp. constructed a five-place plane, known as the Fairchild Model 46. It had a molded fuselage. The wing structures were of wood with resin-bonded plywood covering. The plane was flown in August 1937 and has approval No. 2-545 issued by the Civil Aeronautics Authority. It was assembled in Hagerstown, Maryland, and is today in active service.

The fuselage was formed with veneers over a cast-iron die used in the curing process. Because of the prohibitive cost of the die, this process has been abandoned.

In 1939 an exclusive license on large aircraft was sold to Hughes Aircraft Division of Hughes Tool Co., Los Angeles. Simultaneously Duramold Aircraft Corp. became a 100 per cent owned subsidiary of Fairchild Engine and Airplane Corporation.

Duramold as a process is today jointly controlled by Haskelite and Fairchild, except for the license to Hughes. The interesting non-aviation potentialities are allocated to Haskelite. All aviation developments and production are assigned to Fairchild or Hughes.

The Duramold method requires, like any molding processes, first a form or mold. Unlike conventional practice, the female part permits liberal selection of material; sheet steel, cast metal or wood may be used. This is the non-flexible half. The determining factors for size and construction are the dimensions of the part to be constructed and the quantity to be produced. The male or flexible half of the die is a rubber bag. The non-flexible die gives the solid base for the shape and for applying pressure. The flexible die assures equal pressure all over the surface and gives at all points of curved surfaces pressures that are directed at right angles to the surface. This feature cannot be duplicated by the application of pressure by means of hydraulic or mechanical presses. By this method uniform pressure is applied at all points on compound curved surfaces.

The part to be molded, be it fuselage, wing, nacelle, pontoon or spar, is placed over the form — a layer of wood, a layer of plastic, a layer of wood and another layer of plastic, and so on until the desired thickness is built up. Over the whole is then placed the retaining bag. The assembled aggregate is then placed in the tank and pressure is applied. This is accomplished with steam at 100 lbs. per square inch. The length of cure is variable. Temperatures and length of cure are experimentally determined by measurements with thermocouples, which are installed inside the panels in thick sections of one-half inch or more. Once the optimum

conditions are found for a piece of the desired size, then the predetermined temperature and pressure are maintained in production. Generally speaking, on thin sections of from ⅛ in. to ½ in., it is not necessary to predetermine cure. About 15 minutes are required. When the molds and part are taken from the oven and the part removed, it is finished except for the surface treatment operation.

The most successful plastic bonding agent the company has used is of the thermosetting type. Both viscous dopes and sheets of phenol-formaldehyde resin have been employed. The glue lines by laboratory test and by the more critical standard of actual experience are as strong as the wood.

Mr. Alfred A. Gassner, chief engineer of the company, enumerates some of the features of Duramold plastic-plywood, as follows:

1. The process permits design and construction of monocoque-shell type of aircraft parts such as wings, fuselages, tail surfaces, cowlings and the like, with the structural material distributed to its best advantage and with secondary reinforcing members like stringers and ribs either entirely eliminated or greatly reduced in number as compared to present-day type of construction. A thick skin can be left which is by itself able to carry large compression, shear or tensile stresses, because of the comparatively low density of the construction material. The specific gravity of mahogany-base Duramold is 0.52 compared with a specific gravity of about 2.80 for aluminum alloy. The skin thickness can, therefore, be about 5.4 times the thickness of such a material for the same weight.

In compression-buckling the determining factor is the *EI* value, or the product of modulus of elasticity times the moment of inertia of the member. For aluminum alloy $E=10{,}300{,}000$ lbs. per square inch, for the mahogany-base material $E=1{,}100{,}000$ lbs. per square inch. But the moment of inertia I is equal to $t3/12$ for unit length, and the thickness "t" for Duramold can be 5.4 times the thickness of the aluminum alloy plate. At same weight the plastic-plywood shell would be more than 2.5 times stronger in compression than the unreinforced metal shell, and it would be by 15 to 20 per cent stronger than a metal shell reinforced by long stringers.

2. Riveting is eliminated, and with it all the unevenness of the surfaces of wings or fuselages. Lap or seam joints of sheets with their detrimental effect on drag, are avoided. These two factors, rivets and sheet seams, increase the drag of a production-type all-metal wing by from 30 to 50 per cent over the drag of a perfectly smooth wing in wind tunnel tests. A thin-skin all-metal wing also tends to develop wrinkles or undulations under air loads. The thick-skin Duramold wing is free of such wrinkles under normal flight loads.

Fairchild P. T. 19 Trainers now in quantity production are equipped with spars of plastic plywood. Duramold spars are molded from short lengths of spruce or, in some instances, of other types of wood. They have equal or greater strength than could be obtained in using virgin wood. Plane manufacturers are, therefore, no longer dependent upon the limited supply of long-length straight-grained spruce. Curiously, the cost of molded spars is less than that of cut and trimmed spars, made of one piece of solid spruce.

The Duramold Aircraft Corp. has produced experimental nacelles. The antenna housings on a major airline fleet are this company's product. Production of larger aircraft parts is a near reality. Tanks or ovens large enough to handle full-sized wings and fuselages are on order. One tank, 10 feet in diameter and 28 feet long, will soon be installed. The quick-acting door of this tank weighs 13 tons. An abundance of stress-strain data has been accumulated, assembled, and worked up into the engineering formulas required for production.

"The Summit" head on

Aircraft Research Corporation

Prominent among the companies which have extensively explored with more than pilot production success the use of plastics in manufacturing airplanes is the Aircraft Research Corp. of Bendix, New Jersey. This company molded a small two-place airplane which has been flying for several months and which is now being tested by the CAA. It also has both Army and Navy contracts and recently completed a molded combat plane for the Army Air Corps.

Aircraft Research Corp., organized three years ago by Gene Vidal, has been molding aircraft and other structures using plastics for two and one-half years. During this period of experiment and development, weathering, strength and other tests have been conducted for improving both structures and material.

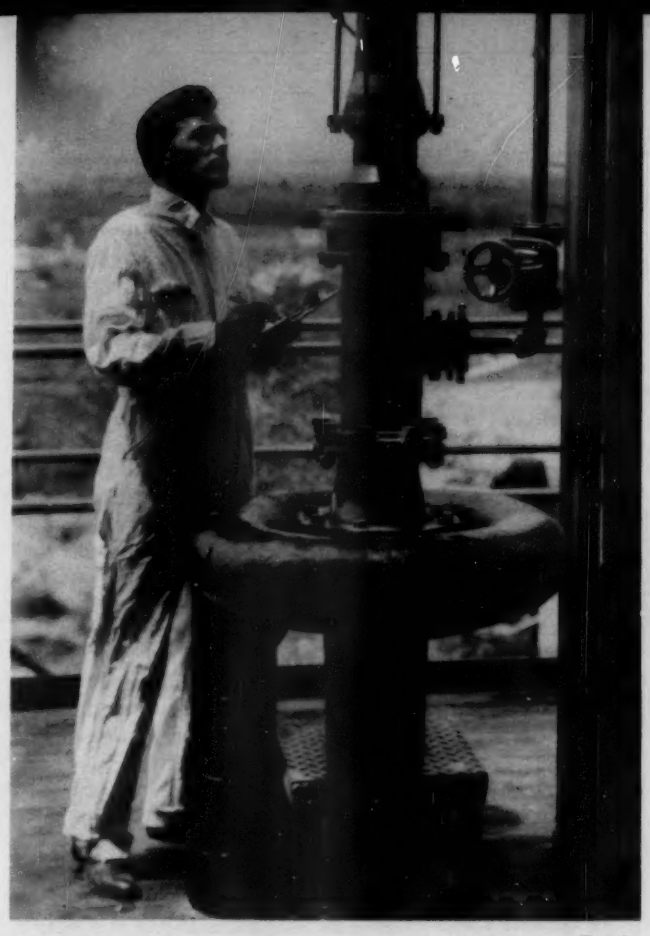
The company, by contract, constructed the forms and molded the body of the Summit plane, which has been flying for several months and which is now undergoing CAA tests. It is the first completely molded airplane *body* in the United States, and, to our knowledge, the first in the world. The wings, fuselage, tail assembly and controls were molded as complete structures.

Aircraft Research Corporation was granted a development contract last July from the United States Army Air Corps and next month will have completed the design, forms and molding of a Basic Trainer airplane. The company has a contract for floats for the United States Navy Bureau of Aeronautics and has already delivered a number of main and wing-tip floats for various types of service and severe practical tests.

They have developed, molded and tested boats, skis, racquets, automobile parts, etc., using the same process. The United States Plywood Corp. is the company's exclusive licensee for the manufacture and sale of boats, automobile parts and skis, and these products are now being made and sold. U. S. Plywood Co. is also a non-exclusive licensee for aircraft parts and is now installing its fifth large pressure tank at Algoma, Wisconsin. A variety of other products, which have promise, are being developed at this time.

The Vidal process, as the Aircraft Research Corp.'s method is designated, is primarily a method of molding, under a fluid pressure and heat, plastic and a reinforc-

(*Continued on page 307*)



Hercules

THE CHEMICAL ENGINEER

WHETHER PEACE OR WAR COMES, THERE IS AN EXPANDING FUTURE IN THE CHEMICAL INDUSTRY

By PROF. WALTER G. WHITMAN

HEAD OF DEPARTMENT OF CHEMICAL ENGINEERING

TODAY'S news of preparations for National Defense highlights our plans for the expansion and development of American industry to meet the problems of a changed world.

Much of this planning is directed toward a group of industries which are inherently chemical in nature — a group which was relatively unimportant before the first World War but which is fast becoming a mainstay of our industrial structure. The petroleum industry, producing gasolines for automobiles and aircraft, fuel for Diesel engines, lubricants for all purposes, and fuel oil for our domestic heaters and for industrial and maritime purposes, is an example. Some idea of the magnitude of this business is evident from figures on tax revenue, which show that the taxes from the petroleum industry and its products amount to over ten per cent of the national tax income.

A key item in the national program is the supply of rubber, which might be cut off by the action of international politics. Fortunately, the products from natural rubber are today much more durable and long-lived than formerly because of intensive research and technical development, and in addition, reclaiming operations on used rubber can be counted upon to an increasing extent. But main technical interest centers today on synthetic products of similar properties, and new words like neoprene, thiokol, buna and butyl are finding their way into the newspapers. These materials, along with other synthetics such as the new fibre, nylon, and high octane, military aviation fuel are representative of today's industrial pioneering. Geographical frontiers have disappeared from this country, but the search for new and better products and methods is proceeding lustily and challenging the best efforts of our modern frontiersmen.

The industries leading this advance are largely in a group which is classified as Process Industry and which includes chemicals, rubber, paints, petroleum, manufactured gas, pulp and artificial fibres. The metallurgy of iron and of the non-ferrous metals is very similar and might well be classified in the same grouping. These Process Industries of course differ markedly among themselves: for example, some make a high cost product which sells at five dollars a pound, whereas others turn out material at a dollar a barrel or at ten dollars a ton. But their basic similarities are more significant than their superficial differences. What are these similarities?

The first common characteristic is the vital role of chemistry in the manufacturing procedure. The raw materials which enter the process are modified not only in physical form but also in chemical composition before they leave the plant as finished products. Sometimes the chemical operations are primarily a removal of undesired contaminants, such as occurs in the cooking

and bleaching of wood chips to make pulp for the manufacture of paper. In other cases the product is entirely different from any of the chemical compounds which were present in the raw material, as in the manufacture of "silk" fibres from air, water and coal. But whether the chemistry be refining or complete transformation, its contribution is all-important to the existence of the industry and to the character of its operations and of its policies.

A second generalization is that the spirit of experimentation pervades these industries. Most of them are comparatively young. The newness of their products is shown significantly by the statement of one of the largest chemical companies: over one-half of its present income is derived from products which were not even on the market ten years ago. This is perhaps an extreme example, but in many cases the developments in the quality of older products has been so marked that the product which was marketed ten years ago could not be sold in competition with today's materials. Industries which are changing so rapidly, as a result of technical progress, are necessarily strong supporters of the industrial research activities upon which their growth is based.

These two major factors, the utilization of chemistry and the spirit of experimentation, have exerted a vital influence on the course which the Process Industries are pursuing. The operations are highly technical, requiring skilled workers. Equipment is relatively expensive, and elaborate instrumentation for close control is characteristic. Furthermore, processes rapidly become obsolete both because of the competition of still newer products and the development of cheaper manufacturing methods. As a result, investment costs are unusually high, and have been estimated as about twice the investment per dollar of product value in comparison with the average of all American industry.

The nature of the demand for men is also somewhat unique. In general there is little need for large numbers of unskilled laborers, and the total labor expense is therefore relatively low. On the other hand, experienced skilled labor is essential to successful plant operation, and these industries are notable for stability of employment and good wage rates.

The opportunities for technically trained men are unusually strong. Research and development programs call for physicists, chemists, metallurgists and chemical engineers; new plant design requires several types of engineers; improvement of processes is carried out under the technical staff, and the actual operating responsibilities are necessarily shouldered by technical men. In recent years there has been a marked influx of men with engineering preparation into the marketing phases, such as market analysis and technical sales. This movement results from the realization that the introduction of new products and the extension of usage requires a thorough technical grasp of the problems and an engineering approach to their solution.

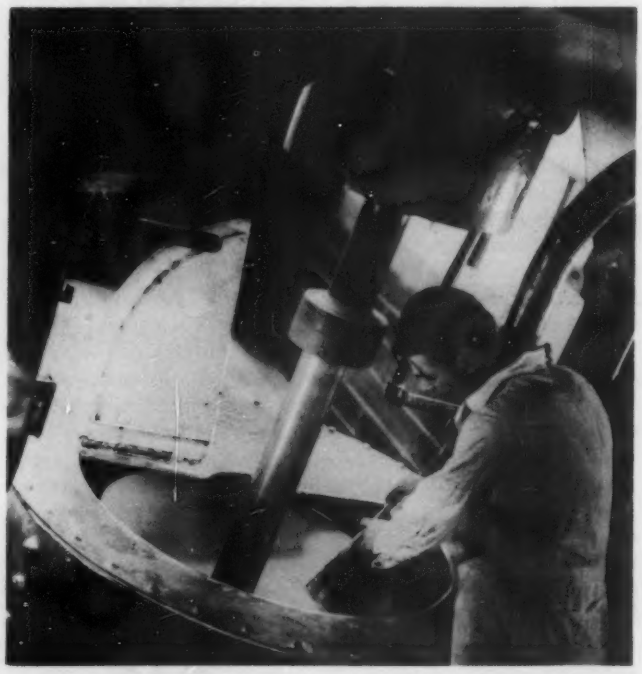
It is not surprising to find that the executive control of such enterprises is entrusted more and more to technical men. The decisions to be made in charting the future course of the business must be predicated upon appreciation of the technical possibilities and pitfalls of new developments, and sound judgment demands a truly research approach. The leadership of Process Industries is well studded with men whose early training was in science and engineering and who have reached their present positions by the path of technical achievement.

The training of the chemical engineer is well adapted to the needs of Process Industry. Applying scientific principles and discoveries to useful purposes is a major objective of his engineering training, and the breadth and scope of his program qualify him to gather for action the diverse threads of research, design, and economic investigation which must be integrated in any sound development.

An interesting educational experiment in training the chemical engineer has been born from the growing appreciation of the functions for which he is being prepared. Last year a selected group of second-year men at the Institute were invited to enter a three-year program in which about fifteen per cent of their time would be devoted to work under the Section on Industrial Relations of the Department of Economics. This plan to include studies on the human problems of industry was initiated by the realization that intelligent management of industry in the future will depend to an increasing extent upon well-informed coöperation between the human elements which make up the complete enterprise. The chemical engineer occupies a strategic position to develop or hamper such coöperation because his work directly concerns operating problems and personnel. This educational project really constitutes another attempt to develop those harmonious relationships in our industrial life which are so necessary to its health and progress.

This picture of the chemical engineer describes him by emphasizing the nature of the industries to whose development he has made marked contributions. They are growing industries — vigorous, pioneering, and vital to our national economy — they afford a wealth of opportunities for the chemical engineer of the future.

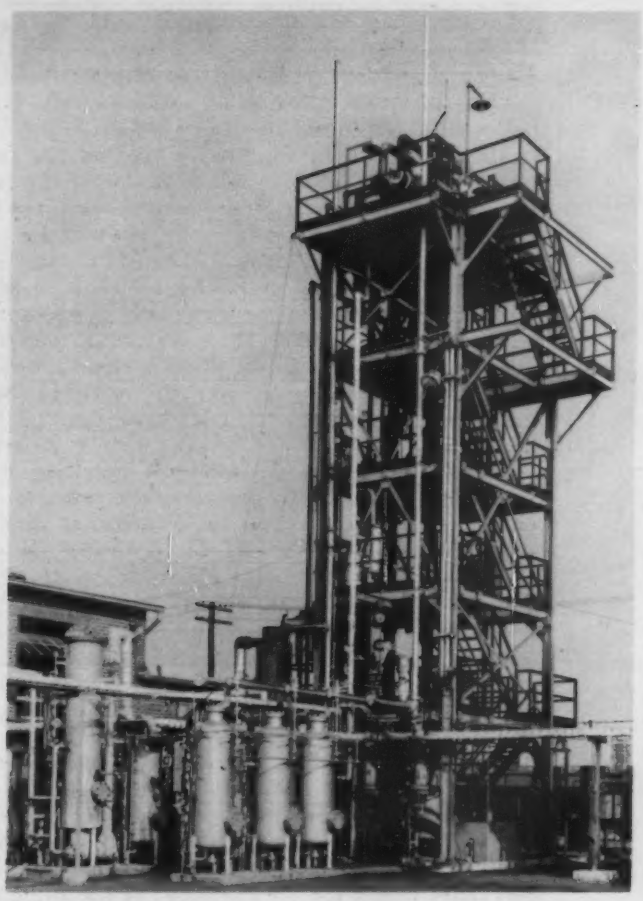
The training of the chemical engineer is well adapted to the needs of Process Industry



SYNTHETIC RUBBERS

LIKE SILK, NATURAL RUBBER MAY SOON BE LARGELY REPLACED BY MAN-MADE SUBSTITUTES

By
J. R. BROWN, JR.
and
PER K. FROHLICH
ESSO LABORATORIES OF THE STANDARD OIL DEVELOPMENT COMPANY



A butyl rubber plant

AS the complexity of the present world conflict becomes greater day by day, we look to our own national economy to detect those places where we are most vulnerable and need protection. Far up in the list of strategic raw materials — in peace as well as war — is rubber. With 95 per cent of our daily needs of this important commodity coming to us from the far off East Indies, our rubber lifeline is indeed exposed to a good half of the worldly sphere. Two questions are being currently raised as a result of this situation:

Have we substitutes to take the place of natural rubber? Can we make these substitutes in sufficient quantities to serve our needs in the event our supplies are cut off?

Behind the answers to these important questions, which are being so earnestly studied today by those responsible for our national defense, lies an interesting story of how the chemists' dream of over half a century ago has finally been brought through the early stages of commercial success to the threshold of extensive production and of wide-scale technical application.

From the earliest times in which natural rubber became an article of commerce the curiosity of the chemist as to the composition and structure of rubber was the cause of much experimentation. As early as 1860 isoprene had been isolated as the parent hydrocarbon of natural rubber, and it was later proved that this would change back into a rubber-like mass on standing. It was not until 1884, however, that Tilden, an Englishman, prepared isoprene from turpentine, which was then converted into the first synthetic rubber whose raw material did not come from the natural product. This work was continued in Germany and Russia with the result that other hydrocarbons were found which could be polymerized to rubber-like products, thus laying the scientific foundation for the later development of synthetic rubbers which were not chemical duplicates of natural rubber itself but were related chemical structures, possessing the more important physical properties associated with rubber.

From this early scientific period we pass to the early commercial period about 1910 when the soaring price of rubber inspired the chemists of England and Germany to seek a less costly synthetic product even at a sacrifice to the natural material in quality.

In England a process was worked out for polymerizing diolefins by means of sodium, a process probably still used today in Russia. The diolefin employed in the polymerization was butadiene which was obtained from butyl alcohol, produced by fermentation methods. Several steps in the preparation and purification of the butadiene are still being employed in similar processes which start with less costly raw materials. Due to the steady decline in rubber prices in the years that followed, synthetic rubber was never produced in commercial quantities by this method, but curiously the development of the butanol fermentation technique served to establish this industry as an important supplier of acetone for the subsequent war, and to help the later development of solvents for the lacquer industry.

In Germany, just prior to 1910, the problem was attacked quite extensively by both academic and industrial chemists alike. They also developed the sodium polymerization method as well as the manufacture of other diolefins such as dimethyl butadiene. In spite of the vast amount of work done at this time, no commercial progress took place until Germany was cut off from her natural rubber supplies by the World War.

At this time the so-called "methyl rubber"— a polymer of dimethylbutadiene — was developed. The 2, 3 dimethylbutadiene employed was obtained from acetone produced by fermentation of potato starch. Although this was probably not the best synthetic rubber known to them, it could be most easily and readily manufactured from the raw materials available at the time. At the close of the war this production was said to have attained a rate of some 4,000,000 pounds per year.

Although the Germans continued to carry on their researches in synthetic rubber after the war, and were joined by the Russians — who made important contributions of their own — the next period of enlightenment occurred about 1926. At this time it became evident that the molecular structure of rubber was perhaps more important than its chemical constitution. The theory that rubber-like properties were associated with the long chain-like molecule resulting from the polymerization of individual isoprene units in the case of natural rubber, led to the conclusion that such a molecular structure might be produced from other sources to give a different chemical constitution, perhaps even with improved properties over the natural product. With such improvement in properties it would not be necessary to have a product which would be cheaper than natural rubber, and the economic handicap of the previous period of development could consequently be at least partially eliminated.

With this incentive, the duPont organization in the United States was successful in developing Neoprene, a polymer of chloroprene obtained from coal, limestone, and salt, by way of acetylene and hydrochloric acid. During this same period the I. G. Farbenindustrie in Germany began the development of the Buna rubbers, which are polymers of butadiene with or without other materials to modify the properties of the product. The source of butadiene has been chiefly acetylene, obtained either from calcium carbide or from the high temperature thermal decomposition of natural gas. The development of similar synthetic rubbers in Russia has been based on the production of butadiene from either petroleum or alcohol obtained from natural starch products.

The close relation between the various monomers, or building units, employed in the polymerization reactions to produce practically all synthetic rubbers, is clearly brought out in the following table showing their chemical constitution:

$CH_2=CH-CH=CH_2$	Butadiene
$CH_2=C(CH_3)-CH=CH_2$	Isoprene
$CH_2=C(CH_3)-C(CH_3)=CH_2$	Dimethylbutadiene
$CH_2=C(Cl)-CH=CH_2$	Chloroprene

The modifiers used in the case of the Buna rubbers are chiefly:

$C_6H_5-CH=CH_2$	Styrene
$CH_2=CH-C\equiv N$	Acrylonitrile

The synthetic rubbers now being produced have shown definite improvements over certain of the properties of natural rubber, and it is largely for this reason that they have been able to secure a place for themselves in spite of their greater cost. The more established types of synthetic rubber and their more characteristic properties can be classified as follows:

Buna (generally accompanied by a number referring to specific physical properties) — a straight butadiene polymer. Rather similar to natural rubber, but surpassed by more recent products of the copolymer type.

Perbunan (also referred to as Buna N) — a copolymer of butadiene and acrylonitrile. Possesses marked resistance to hydrocarbons, such as gasoline and oils, has superior abrasion resistance, better aging qualities, and more resistance to heat than natural rubber.

Buna S — a copolymer of butadiene and styrene. Similar to rubber in behavior to solvents, but possesses better electrical properties, and has superior abrasion, heat, and aging resistance.

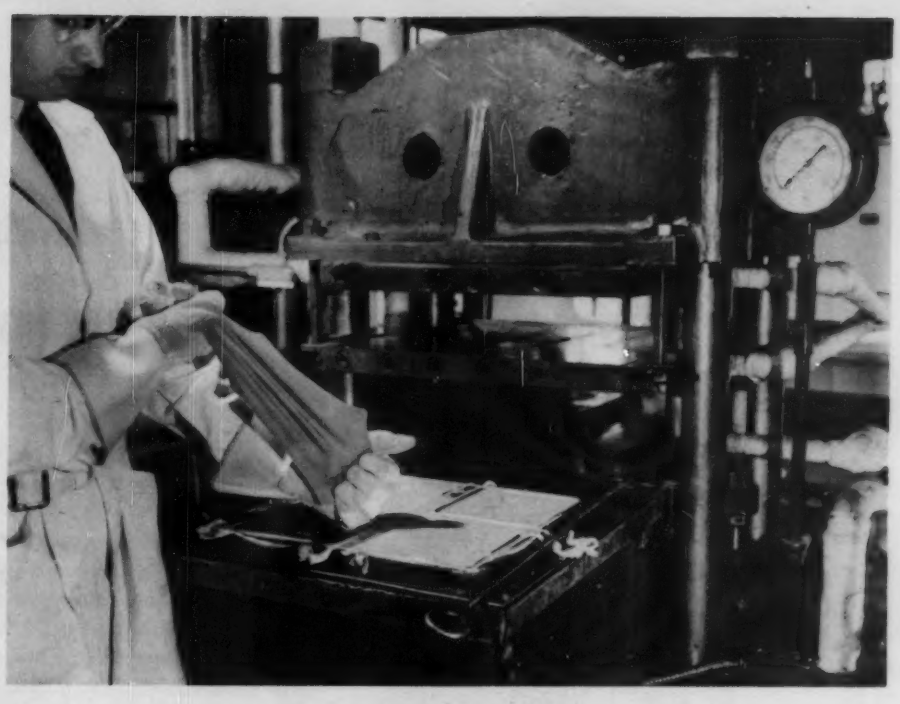
Neoprene — a polymer of chloroprene. Possesses good resistance to hydrocarbon solvents such as gasoline and oils, has better aging resistance, better sunlight resistance, and more resistance to heat than natural rubber.

Other types of polymers or condensation products are sometimes called synthetic rubbers since they do possess certain elastic properties, such as the organic polysulfides, isobutylene polymers, and plasticized vinyl chloride. However, they do not undergo the character-

Forms of crude butyl rubber

istic vulcanization process associated with the unsaturation present in the long chain-like natural rubber molecule. Examples of these latter intermediate products are Thiokol, Vistanex-polybutene, and Koroseal.

Although the earlier butadiene and chloroprene polymers were made by slow batch polymerization methods, the more rapid present-day technique is to subject the reactants which have been emulsified in water to suitable conditions of temperature and pressure in the presence of catalysts to convert them into a suspension or artificial latex of the synthetic rubber, much the same as the natural latex obtained from a rubber tree. The synthetic rubber is then recovered in a manner similar to the recovery of natural rubber from latex.



Butyl rubber is cured in a steam-heated hydraulic press

Within the last year several items of interest in the synthetic rubber field have been announced in the United States. First, the Standard Oil Company of New Jersey announced that it had acquired the patent rights to the Buna rubbers in this country and will begin producing Perbunan made from petroleum raw materials in the near future. Certain of the larger rubber companies will also license under these patents to produce material for their own use. Standard Oil has likewise recently announced as an independent development a new type of synthetic, called "butyl rubber," which is a copolymer of olefins and diolefins made from petroleum by processes more simple and direct than other known synthetic rubbers. Butyl rubber is more nearly like natural rubber in its physical properties, besides possessing remarkable chemical resistance to acids, chemicals, oxygen, ozone, and aging. It has superior electrical properties, excellent resistance to flexure at high and low temperatures, and high resistance to the diffusion of gases. Since it is made largely from simple olefins, rather than diolefins, it is expected to have a cost advantage over other known synthetics of the diolefin type.

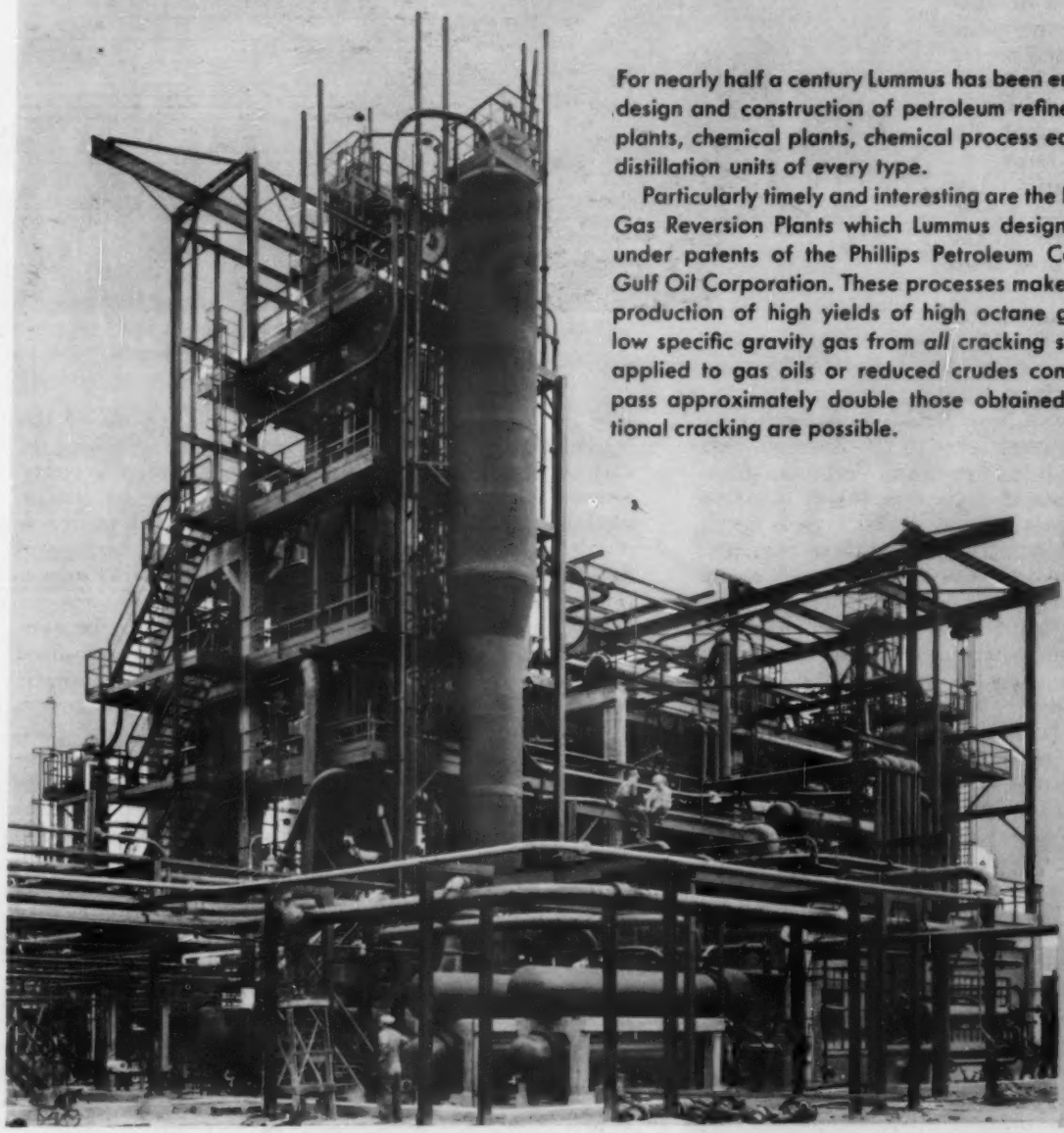
Two other new synthetic rubbers have also been announced recently by two rubber companies — Ameripol by Goodrich, and Chemigum by Goodyear. The rather limited information available on these products indicates that they are the type which is resistant to ordinary rubber solvents, such as gasoline and oils, with good abrasion, aging, and heat resistance. In the absence of specific information other than that they are made from butadiene and certain modifiers, these can be considered to be essentially copolymers of the Buna type. Valuable improvements are said to have been effected in the processing qualities of these materials, so that they can be handled readily in the factory.

The recent development of butadiene-type synthetic rubbers in this country has been based on the parallel development of making the essential hydrocarbon raw material available from petroleum sources at low cost. Butadiene can be most readily produced in large quantities by the dehydrogenation of butane gas now available in huge quantities in the oil well regions of the Southwest, or by the high temperature cracking of various petroleum fractions. An essential step in either process is the purification of the butadiene by special methods, since in general a high degree of purity is required for the polymerization step. The successful development of these methods represents another important chemical engineering achievement, and assures our nation an adequate supply of raw materials for synthetic rubber production in the event of any required demands — either along the line of a normal synthetic rubber development, or in a national defense emergency.

The position as a supplier of low-cost hydrocarbon raw materials comes naturally to the petroleum industry. That it will be capable of meeting any demands which may be made upon it in this respect can perhaps best be appreciated by a comparison of the production of crude oil with the total current consumption of natural rubber. On a weight basis, the consumption of natural rubber in this country is only about one-third of one per cent of the crude oil produced. The estimated total production of synthetic rubber in 1940 amounts to less than one per cent of the natural rubber consumption.

The story of synthetic rubber development is far from finished. Improvements are still needed in our present products, and many defects are still to be overcome. Our increasing knowledge of the structure of rubberlike materials and their behavior is leading to the development of new polymers which are specifically designed to achieve the desired ends. Probably no one type will ever be found with all of the desirable features and none of the weak points of natural rubber. The number of specific types of synthetic rubber will undoubtedly increase, with each one fulfilling a definite place among the others for the many varied jobs to be done, and each one in its special way effecting a substantial technical improvement over natural rubber as we know it today.

Lummus — AN ENGINEERING AND CONTRACTING ORGANIZATION WITH A 50 YEAR BACKGROUND



For nearly half a century Lummus has been engaged in the design and construction of petroleum refineries, alcohol plants, chemical plants, chemical process equipment and distillation units of every type.

Particularly timely and interesting are the Polyform and Gas Reversion Plants which Lummus designs and builds under patents of the Phillips Petroleum Company and Gulf Oil Corporation. These processes make possible the production of high yields of high octane gasoline with low specific gravity gas from *all* cracking stocks. When applied to gas oils or reduced crudes conversions per pass approximately double those obtained by conventional cracking are possible.

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Naphtha Polyform Unit for Production of High Octane Gasoline; built by Lummus.

THE LUMMUS COMPANY, 420 Lexington Avenue New York, N. Y. • 600 SOUTH MICHIGAN AVENUE, CHICAGO, ILL.
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LUMMUS

PETROLEUM REFINING PLANTS

THE POLYFORM PETROLEUM PROCESS

GREATER CONVERSION PER PASS MEANS HIGHER OCTANE GASOLINE AND IMPROVED EFFICIENCY

By DR. E. R. SMOLEY '19
THE LUMMUS COMPANY

THE Polyform process has been in commercial development for the past four years, and is now considered to be in such a state of process refinement that it is being offered to the petroleum refining industry by The Lummus Company on a moderate royalty basis under joint patents of the Gulf Oil Corporation and the Phillips Petroleum Company.

The Polyform process has been used in large scale operation in the plants of the Gulf Oil Corporation for over four years with routine refinery runs of 1,500 to 2,500 hours on stream. At present there are five Polyform units in regular refinery operation having oil charge capacities ranging from 1,500 to 22,000 barrels per day.

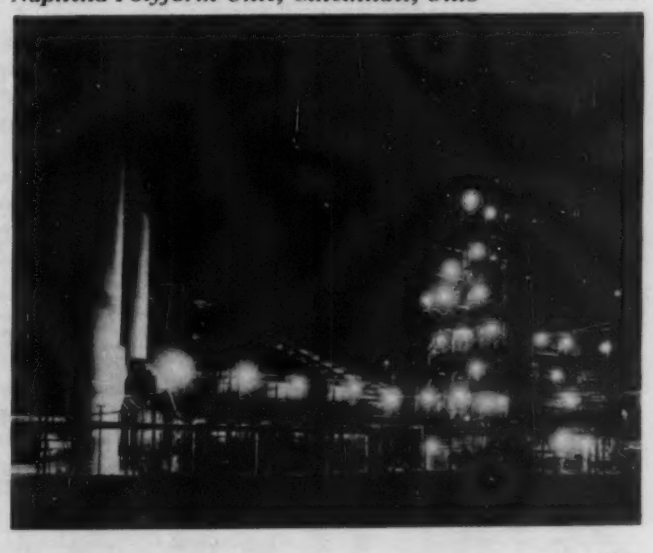
Because of the present trend toward higher octane gasoline requirements, this process is of real interest to the refining industry as it offers an economical means of increasing yield and raising the octane number of gasoline from any refinery and from any type of charging stock. It is possible to convert 20–30 CFR-ASTM octane number naphtha stock, with a boiling range of 250° to 450°F., to 76–82 CFR-ASTM octane number gasoline with high yields. From a whole crude, such as Mid-Continent, East Texas or West Texas, it is possible to obtain a three to four per cent higher overall gasoline yield of 72–74 CFR-ASTM octane number. The specific gravity of the fuel gas produced varies from .70 to .85; the gas is free of butanes and contains only 2 to 15 per cent propanes. Polyform gasolines show unusually good road performance with an appreciation of road octane over CFR-ASTM octane of three to eight numbers.

The basic mechanism of the Polyform process as applied to light hydrocarbons such as heavy naphtha (200°–450°F. boiling range) was conceived a good many years ago as evidenced by the work of Clive M. Alexander (U. S. Patent 1,404,725 application date March 8, 1916). However, it was not until a little more than four years ago that the value of this process in modern refinery technique was recognized. At that time the Gulf Oil Corporation built a large commercial unit in their Pittsburgh Refinery. This unit immediately established the commercial feasibility of the process and was the forerunner of a development that carried the application of the Polyform principle to its present stage of perfection. Polyforming is now applied commercially to all stocks that are cracked by ordinary thermal methods, and one of the largest installations is the unit in Gulf's Port Arthur Refinery that processes 22,000 barrels per day of full West Texas Crude and employs four separate Polyform cycles on naphtha, virgin gas oil, re-cycle gas oil, and reduced crude. At present there are five Polyform units and six gas reversion units in regular refinery operation having an overall charging capacity of 78,000 B/D of oils, propanes, and butanes.

One of the interesting aspects of the history of the Gulf Polyform Process is that it has been largely an engineering development, and until very recently there had been little or no laboratory or small-scale pilot plant work. The Harmarville laboratories of the Gulf Oil Corporation are now conducting all types of Polyform pilot plant operations. Thus, the Process Engineering Department of the Gulf Oil Corporation determined the justification for the first Polyform plant, and it was so attractive to the management that authorization was immediately given for the design and installation of the full-scale Pittsburgh Polyform unit. This unit was designed on sound engineering principles with the aid of little or no laboratory or technical data, and while much has been learned since this first plant was built, the basic engineering design determined for that plant is still employed today.

While the development of the Polyform process represents a distinct departure from prior practice, Polyform units are simple in design and offer no greater operating problems than conventional thermal cracking units. The plant equipment consists of pumps, heaters,

Naphtha Polyform Unit, Cincinnati, Ohio *Lummus*



fractionating towers, heat exchangers, etc., with all of which any cracking coil operator is thoroughly familiar. The instrumentation of these units allows complete automatic control of oil levels, pressures, temperatures, flow rates, etc., leaving to the operators supervision and fine adjustments for optimum results. Investment costs and utility requirements are only slightly higher than those for conventional cracking units. The slightly higher costs are due to higher operating temperatures and pressures used in Polyform operations.

Polyform Theory

It is known that the octane number of gasoline rises with the degree of conversion per pass and that the reaction velocity of cracking rises sharply with temperature.

Inasmuch as the octane number or anti-knock value of the final cracked gasoline from any given stock is largely a function of the degree of conversion per pass, it is desirable to operate at as high a degree of conversion per pass as possible, providing the yield and quality of the gasoline product are satisfactory in other respects.

The yields and octane numbers which can be secured from any given cracking stock depend, to some extent, on the design of the still; but for any stock there is a definite crack-per-pass which cannot be exceeded without serious deposition of coke in the cracking coil, as any pressure still operator knows.

The ordinary thermal cracking process, therefore, has definite limitations in the magnitude of yields and in the octane numbers obtainable.

Any process by which the crack-per-pass can be increased means higher octanes and greater yields of light products. The gasoline yield can be further increased by converting part of the gases produced into gasoline hydrocarbons. The Polyform process does exactly this.

Gaseous hydrocarbons, such as C_3 and C_4 hydrocarbons, are introduced into the Polyforming coils with oils for two purposes:

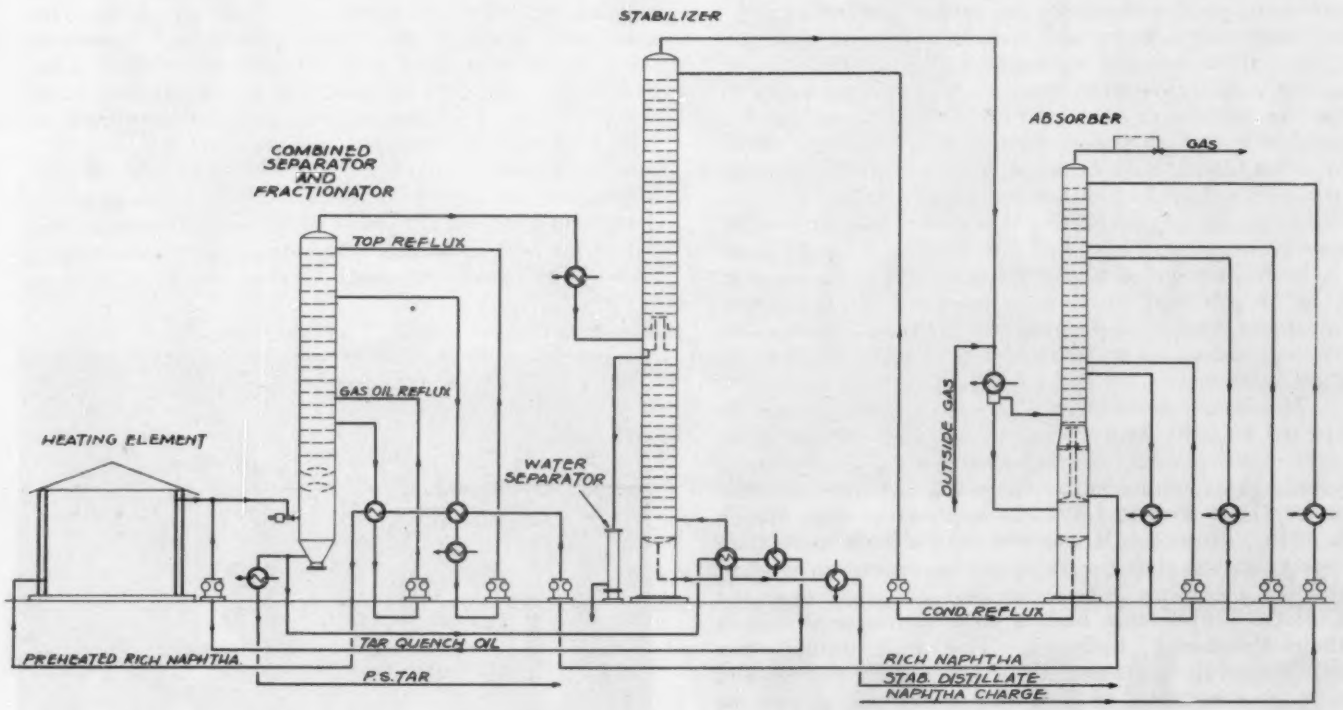
1. In order to effect a higher degree of conversion of the oil when diluted with C_3 and C_4 hydrocarbons than is possible when this oil is cracked by itself.

2. For the purpose of simultaneous cracking of the oil to a higher degree of conversion than is possible when the oil is cracked by itself, and at the same time to effect a certain amount of cracking with subsequent polymerization and other side reactions of the C_3 and C_4 hydrocarbons and oils.

While it is true that there will always be a small amount of cracking of the C_3 and C_4 hydrocarbons in any case, the conversion per pass of these components at temperatures below 950°F. is so small that it may be said that the simultaneous cracking of the oil and polymerization of the C_3 and C_4 hydrocarbons can be practically effected only with oils which can be cracked at temperatures above 950°F. For oils which cannot be cracked at these high temperatures, the C_3 and C_4 hydrocarbons are primarily introduced in order to increase the crack-per-pass of the oil and permit other side reactions.

With respect to heavy oils such as reduced crudes, heavy recycle oils, etc., there is a definite minimum percentage of C_3 and C_4 hydrocarbons in the total furnace feed which should be maintained in order to make possible the increase of the crack-per-pass of the oil. The minimum quantity of C_3 and C_4 hydrocarbons in the furnace feed is indicated to be related to the critical temperature of the furnace feed. It has been found that

(*Continued on page 300*)



NAPHTHA POLYFORM UNIT

FIG. 1

Pittsburgh Plate Glass Co.

PRODUCING GLASS

FROM SAND TO "COKE" BOTTLES, THE CHEMICAL ENGINEER PLAYS AN IMPORTANT PART IN PRODUCTION

By DR. F. W. ADAMS
MELLON INSTITUTE

THE origin of glass-making has been lost in the mists of antiquity, and up until comparatively recent times this art has not experienced the impact of the engineer. For centuries the production of glass articles was a secret closely held in families of glass-makers.

Briefly and simply, it was made by melting together, in a clay pot, a "batch" comprised of sand, lime, and soda. From the pot the glass-blower gathered a glob of glass on the end of a blowpipe. He used his breath, and manipulated the glass to form the desired article. The product was placed in an annealing oven to remove strain and then cooled slowly to room temperature. Some shapes which could not be blown, such as blanks for making plate glass, were cast on tables and rolled, followed by annealing.

Toward the end of the last century, chemists started investigating the chemical nature of glass. Their labors were crowned with enviable success in satisfying the demands of the physicist for optical glasses covering a broad range of density and refractive index.

At about the same time, economic developments in the glass industry led to the merging of glass production into larger, more effective units. In this favorable environment, the mechanical engineer found means for replacing the arduous hand labor with mechanical devices of large productive capacity. Following the World War, technological advances in glass-making opened up new fields, requiring mass production of glass articles of many varieties. With mass production methods and continuous processes have come opportunities for engineering development along many paths.

The basic raw materials mentioned above remain unchanged. The interreaction of these materials and removal of their gaseous by-products complete the chemistry of the process. The mechanical forming of the article is followed by suitable heat treatment to give it the desired physical properties. Actually the process is somewhat more complicated because the addition, either intentionally or not, of other materials to the batch may greatly affect the properties of the product.

Extensive research has been carried out to determine phase relations in, and properties of, multicomponent glasses comprising the more common oxides. Certain minor constituents, particularly metallic oxides such as iron, manganese, and cobalt, markedly color glass when present in almost negligible amount. Other compounds stimulate precipitation of a crystalline phase yielding an opal or opaque glass. Oxides of elements such as potassium, magnesium, aluminum, barium, lead, boron, and phosphorus affect particular properties of glass such as refractive index, density, absorption of specific radiation bands, coefficient of expansion, chemical durability, melting point, viscosity, and length of working range, and are useful in the manufacture of special glasses.

The most evident properties of commercial glass are its transparency, freedom from color, and enduring surface. Regardless of other qualities, these are essential to marketability. Chemical control of raw materials is therefore of major importance. The proportioning of raw materials must be such as to insure continuous control of batch composition. All materials are weighed and very thoroughly mixed to promote rapid reaction rates and to prevent segregation in the furnace. Some manufacturers even go to the expense of preparing briquettes of the batch to eliminate possible segregation during handling and storing, prior to use.

Glass melting has evolved through clay pots of gradually increasing size to present-day tank melting in which over a thousand tons of molten glass are continuously in process. Melting is accomplished at temperatures as high as 2,800°F. in some cases and usually above 2,500°F. Because of the high temperatures involved and the necessity for excluding impurities from the glass, the fuel fed to the furnace is generally gaseous and recuperative; otherwise regenerative heating of the combustion air is necessary. (*Continued on page 309*)

THE TECH ENGINEERING NEWS

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EDITORIAL

THERMODYNAMICS AT TECH

Under the assumption that it is one of the more standard, and thus less talked-about courses of the Institute, the average student has regarded thermodynamics with somewhat of an air of disdain. Now, however, the course is gaining a more conspicuous position among the Institute courses.

It is true that this course formerly presented to the student a theory not very general in its scope, and with problems requiring automatic rather than ingenious methods of solution. Today the staff of instructors and professors realize that the most important problems in thermodynamics are the unsolved ones; it is their purpose that the student gain appreciation of this fact and the ability to do something about it. Their object is to follow and instruct the student as he lays a foundation which will hold him in good stead in industry where he will meet problems requiring a general knowledge of the subject and not, as some suppose, an exceptionally rigorous memory. M. I. T. offers to the student the services of a staff and the advantages of a curriculum that make for a thermodynamics course second to none.

The procedure followed by the staff is described in the following paragraphs by Professor Beattie of the Physical Chemistry Department. This description is an approach from the standpoint of chemical thermodynamics; yet as time goes on there appears to be less and less difference between the thermodynamics studied by the chemical engineer and that studied by the mechanical engineer. Such a condition is derived from the fact that both approaches have in common concern the same fundamental principles.

Professor Beattie's description follows

Thermodynamics deals with the relations between heat and work. Chemical thermodynamics is the study of the work-producing power of systems and of the equilibrium properties of systems, especially systems in which chemical reactions may occur. Many of the relations, such as the equations for the boiling and freezing point of liquids, maximum yield of chemical reactions under given conditions, etc., that are derived in their exact form from thermodynamics, were first obtained in approximate form from experimental investigations. The study of thermodynamics in the chemistry curriculum of the Institute begins in the first and second years with the application of some of these simple laws to various systems. Derivations are not, in general, given. In the third year more exact relations are studied, and towards the end of the year these relations are correlated by means of the first and second laws of thermodynamics. In the senior year the two laws of thermodynamics are the starting point for a logical and fairly rigorous treatment of the subject matter of the third year's work.

Thus, in his first two and a half years' work, the student learns the various more or less simple relations for the equilibrium properties of systems and the conditions under which they apply. In the remaining time, he studies the correlation and derivation of the relations by means of the two laws of thermodynamics.

In the Institute's graduate courses the logical and rigorous methods of rational thermodynamics are presented. Here the emphasis is on the methods used by such men as Carnot, Clausius, Kelvin, and Gibbs. The complications introduced by the existence of a gravitational field, a large surface, etc. are not neglected. The applications of the general relations of thermodynamics to specific systems are made with as few simplifying assumptions as possible and the probable errors introduced by these assumptions are pointed out.

Experimental research in the field of thermodynamics is offered by the staff of the Research Laboratory of Physical Chemistry. Investigations in progress are concerned with: the properties of substances at low temperatures and at high pressure, the properties of solutions both aqueous and non-aqueous, galvanic cells, chemical equilibria, the effect of light on chemical reactions, and the thermodynamic temperature scale.

ACRYLONITRILE

(Condensed from *Chemical Industries*, July 1940)

A few years ago, natural rubber seemed good enough to put "under, over, and about" us — but now substitutes that have come out of the laboratories of the world are slowly pushing it into a secondary position.

Although synthetic rubber is interesting enough, to make it on the spot by mixing two chemicals seems, perhaps, a little difficult to imagine. This is, however, the very purpose of American Cyanamid's acrylonitrile — for when combined with the petroleum by-product butadiene, it becomes the source of a synthetic rubber.

Acrylonitrile is an unimpressive looking substance. It is a colorless, nearly odorless liquid which boils at 77° C. It is non-corrosive and stable when pure; although when certain foreign matter is present, it either disintegrates rapidly, or refuses to react to form rubber. Because of the high degree of purity with which it is manufactured, little trouble results in this respect.

What is of even greater significance is the quality of the substance formed. Its strength, resistance to wear and abrasion, stability under the action of heat and light, and resistance to attack by oils, grease, gasoline, and certain organic solvents render it useful for a myriad of purposes. Gasoline and oil hose, conveyor belts, gaskets and packings, machine mounting blocks, and protective clothing are only a few of the possibilities.

The big question mark associated with synthetic rubber at present is its cost, which is high when compared with natural rubber. It is claimed that acrylonitrile, though still in its embryonic stages, can bring these costs down to a level with those of the natural product. What is even more important, if our supply of natural rubber were cut off, the synthetic product could be produced at a rate that would accommodate any demand. The raw materials that are involved in its manufacture are here in abundance — butadiene from petroleum and acrylonitrile from calcium cyanamide. All that is needed is expansion of production facilities; then low-cost synthesis of rubber will no longer be a thing of the future.

Acrylonitrile was not something that was accidentally discovered, as were sulfanilamide and certain other substances. It was due, rather, to patient, tedious research. Until recently it was a practically unknown chemical, since all previous information about it had been vague and inaccurate. As soon as a method of analyzing the compound was discovered, its usefulness and activity were readily noted. Yet, since acrylonitrile is still a new and far from completely understood chemical, its utilization in the manufacture of synthetic rubber may be of secondary importance. Future research and eventual application to manufacturing processes may find it of even greater value to national industry.

ALUMINA

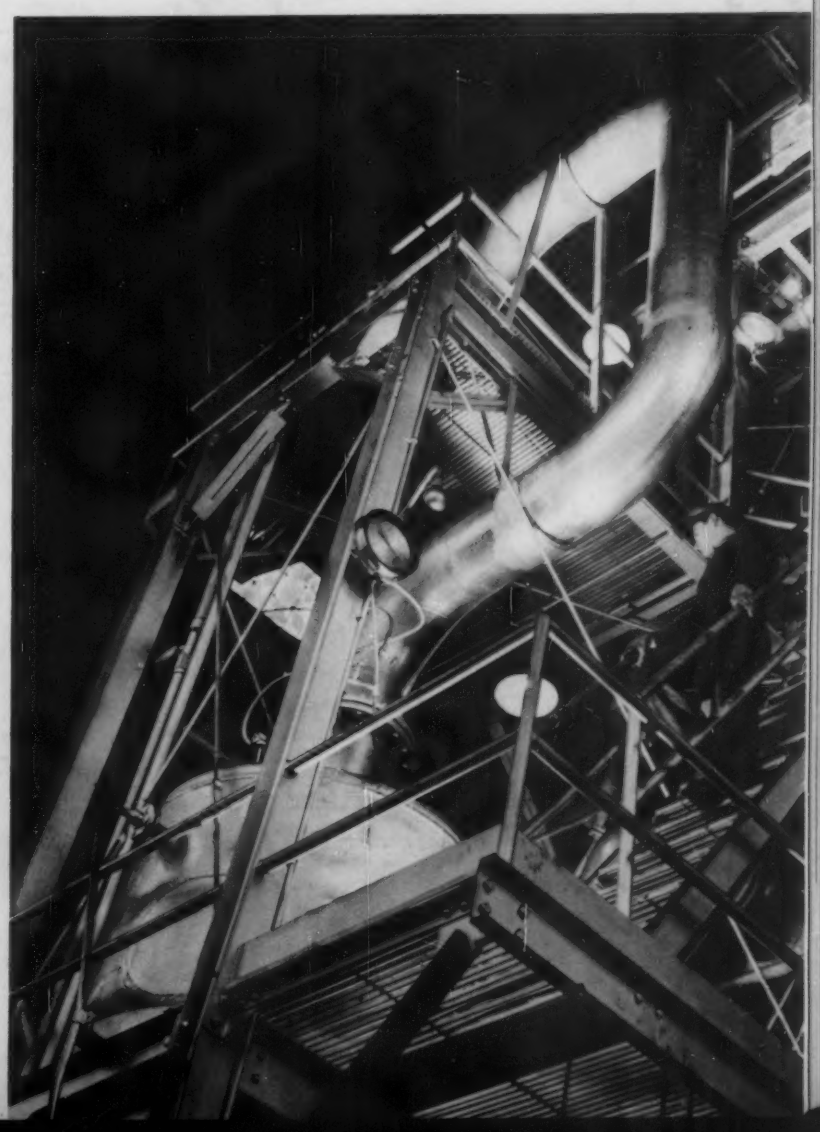
(Condensed from *Chemical and Metallurgical Engineering*, October 1940)

One of the great new plants that is helping to change the South into an industrial district is The Aluminum Ore Company, a subsidiary of the Aluminum Company of America. This plant is situated in the Port of Mobile in order to be accessible to the company's ships bringing the raw material, bauxite, directly from deposits across the Gulf of Mexico. The individuality of this plant lies in the fact that its production is limited to one product, and that is made in an enormous volume.

The principal raw materials that are used in making alumina are bauxite, lime, and soda ash. The process is outlined briefly as follows.

The bauxite is finely crushed in hammer mills and all tramp iron is removed with electric magnets. This ground bauxite is then mixed with ground quicklime into a liquor. The weight ratio of the substances in this liquor is determined by laboratory analysis. This liquor is now a solution of caustic soda and crushed bauxite. The caustic soda dissolves alumina from the bauxite forming a solution of sodium aluminate and leaving in suspension the impurities of the bauxite. The sodium aluminate liquor still contains a syspension of impurities known as red mud. This impurity is removed by filtration. The purified liquor is then cooled and sent to precipitation tanks, which, when full of liquor, are each given a seed charge of previously precipitated aluminum tri-hydrate. The contents of each tank are circulated between thirty and sixty hours; when the circulation is finished, the contents of the tank are pumped into thickeners, where the separation of the precipitated hydrate and the liquor takes place. Upon leaving the thickeners, the hydrate goes through a series of washing thickeners. The hydrate is diluted with successively weaker wash waters in a counter current wash after leaving each wash thickener, and then the washed hydrate is pumped into a storage tank in the calcining department. From the bottom of these tanks the hydrate slurry flows into kilns where it is heated to 1800° F. It is then cooled by a blast of cold air. The process is then completed and the alumina is shipped to the reduction plants of The Aluminum Company of America.

This whole process is carried out with the newest and most efficient type of equipment. It illustrates the effectiveness of producing only one product in a single plant.



THE POLYFORM PETROLEUM PROCESS

(*Continued from page 296*)

when cracking a mixture of an oil and C_3 and C_4 hydrocarbons at temperatures lower than the critical temperature corresponding to the mixture of the oil and the C_3 and C_4 hydrocarbons, this oil cannot be subjected to more severe cracking conditions than if the oil were cracked alone. This is attributed to the following.

When the temperature of an oil in a cracking tube is below the critical temperature of the oil and above its critical pressure, there always exists a vapor phase and a liquid phase in the tube. The liquid phase is suspended in the vapor phase as minute oil particles which, due to the turbulence in the tube, are thrown out against the tube walls covering them with a thin oil film composed of the heavier components of the oil.

As the heat transmitted through the tube wall to the mixture of vapor and oil in the tube has to be transmitted through the oil film, the coking characteristics of this mixture are determined by the coking characteristics of the oil film in the tube. As long as this oil film exists, gas dilution of the oil will not make it possible to crack the oil to a more severe degree than if the oil were there by itself. However, as the percentage of C_3 and C_4 hydrocarbons in the furnace feed is increased, we finally reach the point where the critical temperature of this mixture is equal to the temperature at which the oil can be cracked by itself. At this point only one phase exists, namely, a vapor phase. The oil vapors and the C_3 and C_4 hydrocarbon vapors will hence form a perfect solution, and the film on the tube wall will be of the same composition as the composition of the main body of hydrocarbon vapors passing through the tube.

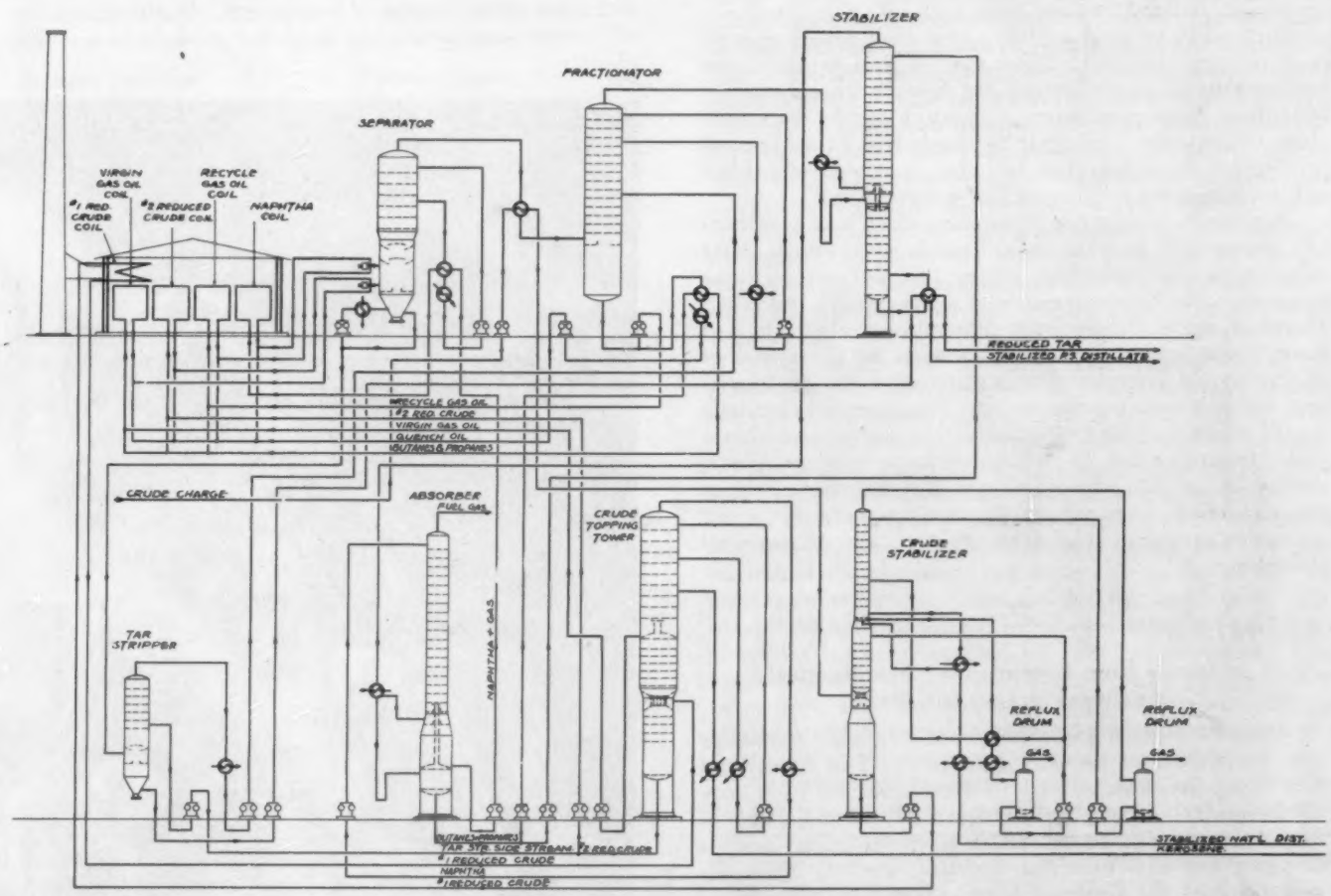
Generally speaking, the gasoline produced per pass for oils above heavy naphtha boiling range may be increased from 1.5 to 2 times the crack-per-pass obtained in an ordinary thermal cracking unit by employing the Polyform principle.

Types of Polyform Units

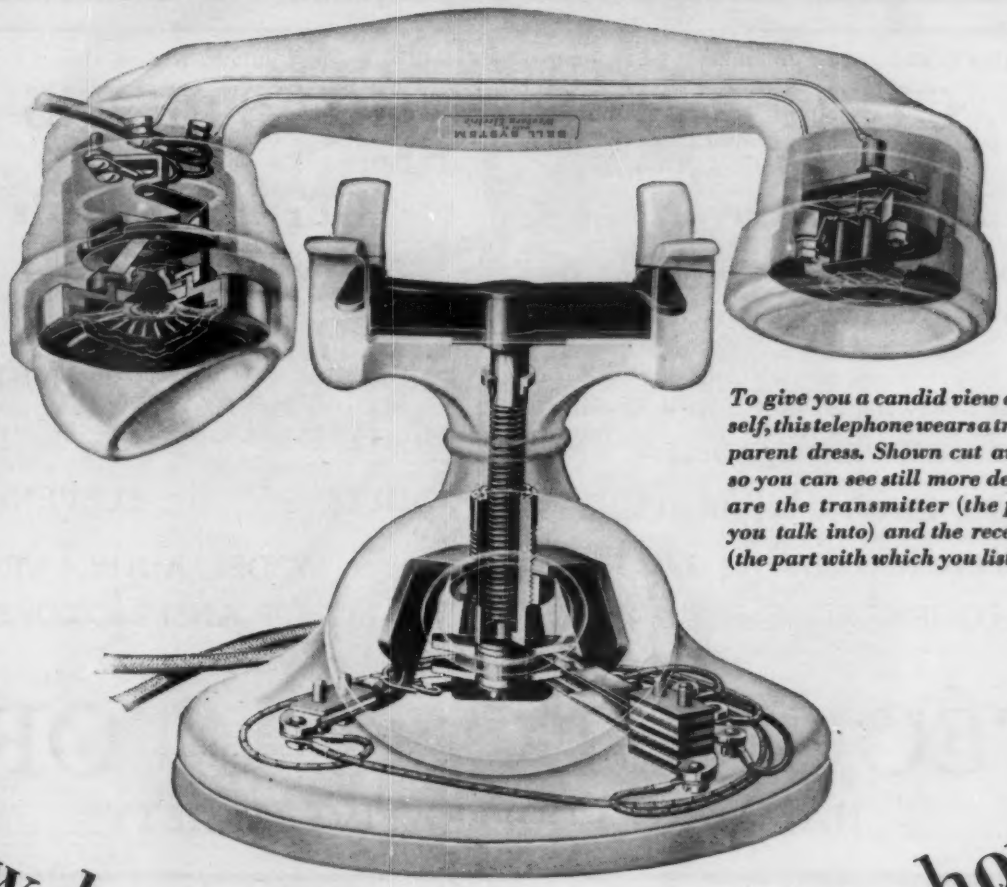
To illustrate the flexibility of the Polyform process, the following descriptions of different types of Polyform units now in service are given with simplified flow diagram and typical yields. Figure 1 shows the simplest type of a once-through Polyform unit. This type of unit is particularly adapted for polyforming of naphthas, kerosene and light furnace oil, with simultaneous polymerization of C_3 and C_4 hydrocarbons from other cracking units. The unit consists of the same elements in any ordinary type of cracking unit, such as heater, separating and fractionating tower, stabilizer and absorber.

The cold naphtha charge is used for absorption oil in the absorber, which is equipped with sidestream coolers for removal of heat absorption for full control of absorption, and to give desired gas circulation. The rich oil from the absorber constitutes the furnace charge. A second absorber, not shown on flow sheet, may be added using light gas oil reflux for absorption oil to extract the C_3 and C_4 hydrocarbons from outside gases charged to the unit at lower pressures.

Ordinarily, outside gases can be discharged directly



FOUR COIL COMBINATION CRUDE POLYFORM UNIT.
FIG.-2



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into the naphtha absorber if in liquid phase or into vapor line between stabilizer and pre-condenser if in vapor phase.

Recirculated bottoms from the combined separating and fractionating tower are used for quench oil to the tube outlet ahead of the reducing valve in order to avoid coke formation in the transfer line and separating tower. The excess heat in the tar quench oil is usually sufficient for satisfactory reboiling of the Polyform distillate in the stabilizer. The combined naphtha and absorbed gas furnace charge is preheated to approximately 500° to 550° F. in trap-tray and gas-oil sidestream high pressure heat exchangers before entering the furnace. The furnace is usually designed with two chambers, one heating section and one soaking section, to permit full control of Polyform reactions.

Typical operating conditions for this type of unit are:

Back pressure on heating element	1,000–1,500 lbs./sq. in.
Tower pressure	300– 400 lbs./sq. in.
Outlet temperature from heater	1,020–1,125°F.

Four-Coil Combination Crude Polyform Unit

Figure 2 is a simplified flow sheet of a 22,000 barrels per day crude topping and Polyform unit at the Gulf Oil Corporation's Port Arthur plant. The only products from this unit are stabilized straight-run gasoline, stabilized polyformed distillate, Bunker "C" fuel oil and dry gas of .78 to .84 specific gravity. In one unit it replaces the conventional type of combination units, thermal or catalytic polymerization unit, gas compression and absorption plant, crude and pressure still distillate stabilization plants.

The general flow is as follows: Crude is charged through heat exchangers into the high pressure crude flash tower from the top of which unstabilized straight-run gasoline is removed. The straight-run gasoline is stabilized in the stabilizer section of the crude flash tower, and from here is passed to running tanks. The Number 1 reduced crude is pumped through a crude heating coil into the atmospheric tower from the top of which a straight-run naphtha cut is removed, condensed and pumped as absorption medium to the top of the absorber. From the atmospheric topping tower a furnace oil or kerosene sidestream can be removed, if required. Below the furnace oil drawoff a virgin gas oil cut is removed. This virgin gas oil cut of 1.0–1.5 NPA color and approximately 700°F. end point is charged hot to the virgin gas oil Polyform coil with its allocated C_3 and C_4 diluent. In this coil, the gas oil is polyformed once-through to between 34 to 45 per cent gasoline production per pass.

From the bottom of the atmospheric tower the Number 2 heavy reduced crude is charged hot through the Polyform vis-breaker coil together with the heavy tar stripper sidestream and required C_3 and C_4 diluent. A conversion per pass of approximately 14 to 16 per cent is obtained in this coil. The light recycle stock from the base of the fractionating tower of approximately 1.5 NPA color and 700 end point is likewise

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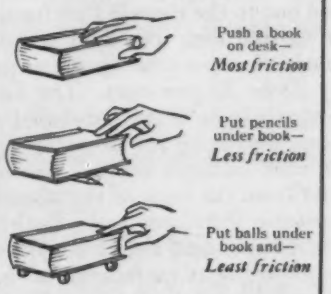

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charged hot to the recycle Polyform coil with the proper C_3 and C_4 dilution. The light recycle stock is subjected to a conversion per pass (gasoline produced) of approximately 25 to 32 per cent. The C_3 and C_4 diluent for these three coils is all furnished as condensate from stabilizer overhead and is composed of approximately 25 per cent butanes and 75 per cent propanes. Rich naphtha from the base of the absorber is polyformed in the naphtha Polyform coil. Both the C_3 and C_4 condensate diluent and the rich naphtha are preheated in high pressure heat exchangers to between 550° to 620° F. before being charged to cracking coils. All four coils discharge into one common separating tower, where the tar is reduced to 10° to 12° A.P.I. gravity without any difficulty. The tar is later reduced with steam in the atmospheric tar stripper to any desired gravity, such as 2° A.P.I.

The type of pyrolytic conversion in this unit is truly selective. All virgin stocks are once-through polyformed before entering the tower system. For this reason, the recycle stock is a real recycle oil, highly refractory, with aniline point of 30 to 35, as compared with 150 for virgin gas oil and 75 to 80 aniline point for recycle stock from thermal cracking units. Typical operating pressures and temperatures for this unit are as follows:

Back pressure on naphtha coil	1,000–1,200 lbs./sq. in.
Back pressure on recycle coil	1,000–1,200 lbs./sq. in.
Back pressure on virgin gas oil coil	500– 600 lbs./sq. in.
Back pressure on red. crude coil	500– 600 lbs./sq. in.
Tower pressures	350– 400 lbs./sq. in.
Outlet temperature of naphtha coil	1,060–1,070°F.
Outlet temperature of recycle coil	1,000–1,010°F.
Outlet temperature of virgin gas oil coil	995–1,000°F.
Outlet temperature of red. crude coil	915– 930°F.

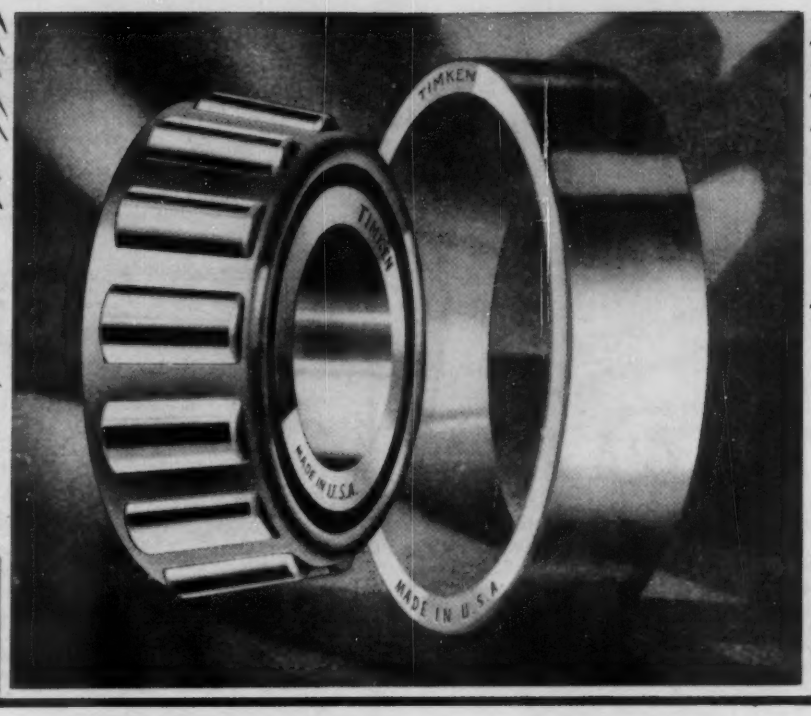
Treating of Polyform Distillate

The treating of Polyform distillates is no different than the treating of conventional thermal cracked distillates and presents no added problems. Polyform gasoline made from sweet naphtha or crude may be cut directly off the unit and blended into a final colored gasoline after the addition of gum inhibitor. For use in water-white gasoline blends, Polyform distillate from sweet naphtha or crude may be clay-treated, resulting in a distillate of +30 color, an increase in CFR-ASTM octane of 0.5 to 0.75 number, a decrease in acid heat, and an increase in gum inhibitor response.

Polyform gasoline may be sweetened by any accepted sweetening method, such as doctor sweetening, copper sweetening, lead sulphide sweetening, etc.

Properties of Polyform Gasoline

Octane Number. The octane number of Polyform gasoline depends, like the octane number of all other cracked gasolines, to some extent on the characteristics of the charging stocks. In general, the highest CFR-ASTM octane number can be obtained from a naph-



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EDUCATIONAL OPPORTUNITIES AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

thenic charging stock of low sulfur content and the lowest octane number from a paraffinic stock, and from high sulfur stocks. However, in naphtha polyforming, it is always possible to produce a gasoline with an octane number, CFR-ASTM, of 75 to 77, regardless of the characteristics of the charging stock.

Polyform gasoline is characterized by having a very much higher appreciation between CFR-ASTM octane ratings and CFR-Research octane ratings than ordinary thermal cracked gasoline. The spread between the ASTM and Research octane numbers of an ordinary thermal cracked gasoline is of the order of 5 to 9, while the spread for a polyformed gasoline is of the order of 9 to 14.

Polyform gasolines have excellent blending values in blends of straight-run gasolines and naphthas. The blending value of Polyform gasoline with thermal cracked gasoline of 68–70 octane number, CFR-ASTM, is practically the same as the clear octane number; the octane number of the blend being close to the arithmetic mean of the octane number of the components.

The lead susceptibility of Polyform gasolines for the same starting octane number compares very closely to thermal cracked gasolines and is influenced similarly by sulfur content.

At the present time two large Polyform units are under construction and several are under active consideration by large refiners in various parts of the country. The total capacity of Polyform and Gas Reversion Units operating and now under construction amounts to 78,000 B/D of crude, naphtha, and light hydrocarbon charge. In view of the moderate initial investment required for Polyform plants and the excellent properties of the gasoline production, the Polyform process will undoubtedly find a wide application.

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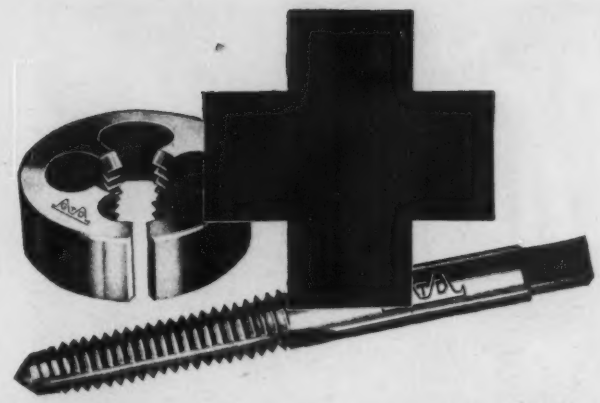
What benefits are derived from soliciting engineering students who as yet have nothing to do with business? The answer is that they are soliciting good will which will pay dividends in the future. You and I are the ones that in the years to come will be dealing with these companies. We are the purchasing agents who will be buying their goods, or we may be selling goods to them; in any event it is then that their present investment in advertising with the college magazines will pay dividends. For through their continued advertising we have a knowledge of their functions, of their personnel, and of the services they perform to the people of the world. All of this background of these companies will not be forgotten by the students who are the important men of tomorrow.



FIRST AID IN THE FIELD

Some day, when you are in industry, things may go badly because a tap, a die, a twist drill, a reamer or a gage isn't doing the work it should.

If such a day comes to you, remember this: G.T.D. Greenfield, the world's largest manufacturer of threading tools maintains a force of some 40 experienced field engineers *for just such days.* A call for the *"Greenfield"* man will always help.

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MOLDED AIRPLANES

(*Continued from page 288*)

ing material such as veneer, which have been placed in the slots of and wrapped about the inexpensive but properly contoured and slotted wooden forms, in such a manner that completely reinforced structures with skin and structural members welded simultaneously into a single unit are the result of the "cooking."

The process is simple, quick and inexpensive, and adaptable to mass production of airplanes. Once the wooden forms, which can be used repeatedly, are completed, neither skilled labor nor expensive tools are required to make the airplane bodies. Both plastic and veneer are inexpensive and available. Streamlining and curving is no more costly and difficult than flat work. The structures can be completed at but a fraction of the labor and material cost of the present-day fabrication and assembly methods it is claimed. They report that their latest wing design, recently load tested, is 40 per cent lighter than present day comparable airplane wings.

Both thermosetting and thermoplastic types of bonding agents have been used. Excellent results have been achieved with interlayer sheets of vinyl butyral resin.

The company has by the Vidal process successfully molded reinforced fuselages, wings, elevators, flaps, ailerons, stabilizers, vertical fins, nacelles, bomb doors, floats and various types of controls.

Plastic-plywood wings made by the company have withstood strength, weathering and vibration tests. They have fulfilled the commercial factor of safety requirement of 6½ and Army safety factor of 9. The seamless feature of the Aircraft Research fuselage is important. The fuselage from fireboard to tail tip acts as a single unit. A commercial plane equipped with 75 hp. motor will cruise at about 95 miles per hour, but the Summit plane constructed by the Vidal process, equipped with the same power will cruise at 125 miles per hour because all surface contours are smoother, conforming more closely to aerodynamic lines. The company awaits final governmental approval before producing the first 100 units of this class of plane, now on order. Incidentally, craft of this type would serve excellently as military trainers.

Large-scale production by this method is possible. A process licensee, who is using this method, is manufacturing dinghies and small sailing boat hulls with modest plant facilities at the rate of 15 units per day.

Timm Aircraft Company

The Aermold process has been under development over the past two years by the Timm Aircraft Co. of Van Nuys, California, and technical phases are being directed by Mr. Walter A. Hite. This firm recently flew its first plastic-plywood plane. The ship is a primary trainer conforming to Air Corps and CAA specifications. In its trial flights instability, maneuverability, in fact in all respects, according to the report, it performed satisfactorily.

The Aermold method involves, first, the construction of dies or forms to the desired contours. Then spruce veneers are superimposed one upon another using a thermosetting phenolic resin sprayed or otherwise applied on each layer during the assembling to serve as

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the bonding agent. The assembled structure is placed in an oven where it is cured. The phenol-formaldehyde resin under heat and slight pressure reacts to become a hard, fast bond. The specially constructed large oven is 10 feet wide, 10 feet high and 40 feet long.

Load tests were recently conducted on horizontal tail surfaces similar to those used in the Timm Trainer. These were loaded to 120 per cent of the design load. At the tip the maximum deflection was 1.38 inch. When the load was removed, it was observed there was no measurable permanent set. Timm has made no effort to design for minimum weight since it is most interested in manufacturing economy.

The Aermold process normally contemplates that surfaces will be bonded in the oven or cooker within an hour after the bonding agent has been applied. In the event that the bonding material has begun to harden, it may be restored to normal operating consistency by treating with a thin film of water. Subassemblies are normally subjected to temperatures of 100° F. to accelerate the setting properties of the binder. Complete assemblies are placed in the oven at a temperature of approximately 180° F. for a period of two hours. During this time, strict attention is given to careful humidity control.

The baking process results in all of the various elements being fused into a single mass. The result is a smooth, light, efficient plastic-plywood structure. Pressures on the tank for the cure range from 50 to 150 lbs. per square inch according to the amount of impregnation desired. Timm manufacture is not as yet on a large-scale production basis. The preliminary experimental work has been completed and has indicated promising possibilities in this direction.

The fundamental bases for the current progress in plastic-plywood have been the development of a satisfactory forming or molding method, the development of satisfactory inert bonding agents, the improvement of finishers, the economy of processing, the low cost of construction and the superior aerodynamic qualities.

Paralleling the progress made in the plastic-plywood materials has been the improvement of the surface coatings or finishes, for both inside and outside protection. Various types of synthetic sealers and sprayers are in use and development work is going forward to see if the drying time of coatings can be reduced to facilitate greater production speed.

The present urgent demand prompted by the national defense program has accelerated developments. The manufacturers of plastic-plywood, it is reported, are delivering sub-structures to meet exacting aerodynamic specifications. Complete planes are undergoing tests on the rough anvil of experience. The industry is preparing for the increasing demands which are confronting it. A program of intensive research is under way, and the plastic manufacturers are actively coöperating by furthering research development.

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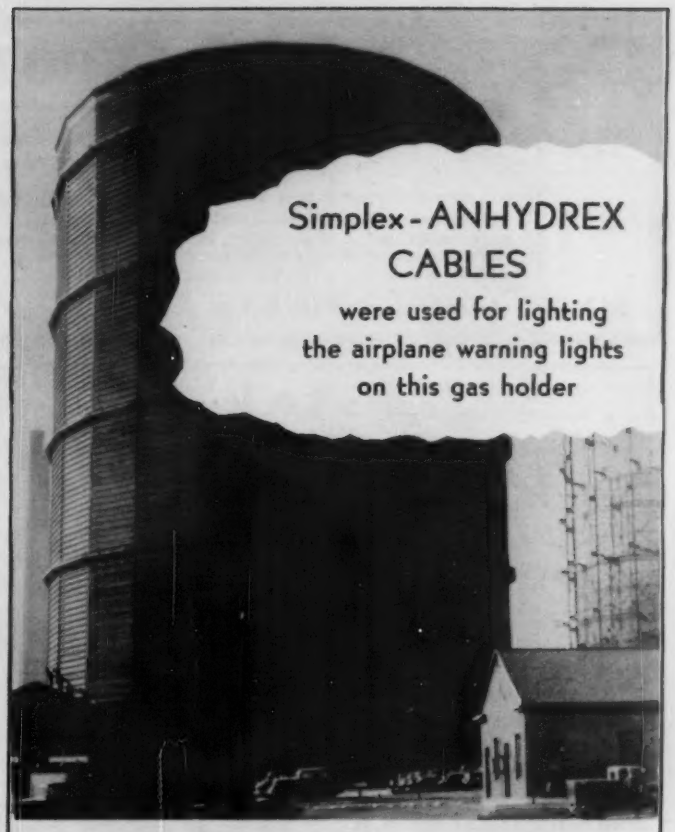

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PRODUCING GLASS

(*Continued from page 297*)

Furnace design offers many interesting applications of chemical engineering. The thermal efficiency of high temperature operations is generally low and susceptible to improvement.

Heat distribution in a furnace containing a number of pots must be carefully worked out to get uniformity of operation from pot to pot. In a tank, the heat distribution must be arranged to induce suitable convection currents to prevent by-passing of batch from the melting to the refining end of the tank. A completely reacted, gas-free glass must be delivered by the tank. Here indeed is a happy hunting ground for the chemical engineer who is interested in combustion, heat transfer, and furnace design. Corrosion of refractories is very severe under these conditions, and outstanding developments of cast refractories to meet this duty have been made recently. The sound application of physical chemical principles has been of inestimable value to the solution of this problem. In the furnaces used for melting glass for fiber production, platinum has found favor to prevent contamination of the glass with corrosion products. Application of other corrosion-resistant metals, such as chrome-nickel alloys, in special locations has been successful in tank operation.

The step of transforming molten glass into a solid article is an engineering operation in which the chemical engineer can greatly assist. It requires a precise control of cooling rates under conditions of high heat flux while the glass is still molten, followed by annealing and cooling at very low thermal gradients to prevent thermal strains. Heat fluxes as high as 200,000 B.t.u./hr./sq.ft. are frequently encountered in the forming operation, while annealing of the 200-inch telescope mirror required a cooling time of about a year to reduce its 20-ton mass from the annealing temperature to room temperature.

While melting methods are common to all types of glass, forming the article is accomplished in many different ways, and each article is a special heat transfer problem in itself. Glass has a working range between its melting point and the point where it stiffens so that it can no longer be manipulated. This range varies in temperature level and range for each different chemical composition.

Considering that the designation "glass" defines a type of structure, it should be realized that this type of structure can be obtained in an infinite variety of ways, by controlling chemical composition. Commercial glasses while somewhat limited by economic considerations may be produced in great variety. Some of the effects of differences in chemical composition are reflected in differences in heat transfer rates. On certain bottle machines it has been found that some colors of bottles may be produced at higher rates than others because of differences in emissivity and hence rates of radiant heat loss. Changes in chemical composition also affect thermal expansion coefficients and thermal conductivities. Release of strain during annealing and permissible thermal gradient during subsequent cooling involve careful design of heat transfer to get maximum production and minimum breakage in use. Annealing lehrs are frequently required to handle containers of various shapes and sizes, each requiring its own partic-

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ular treatment. An appreciation of the heat transfer conditions involved, coupled with a knowledge of the strength of construction, should make the chemical engineer well adapted to handle production and get the most out of his equipment.

The production of window glass offers a splendid example of the importance of heat transfer. Liquid glass is pulled up from the surface of a molten pool at a uniform, continuous rate and caused to solidify into a continuous flat sheet of uniform thickness. The supply of liquid glass to the pool must be regular and free from eddies or other mechanical disturbances which would show up in the finished glass; its temperature must be absolutely uniform. Cooling must be applied by radiant coolers so that the glass will be drawn into sheet form without irregular stretching or wrinkling, and without contacting anything which could damage its surface finish. This operation must be accomplished at a high temperature level, starting with a quite fluid glass and regulating the cooling rate to synchronize with the speed of travel of the sheet until it has been transformed into a continuous solid ribbon.

Blown ware offers similar problems, frequently of an entirely different order of magnitude. Lamp bulbs of nearly paper thinness produced at a speed of several hundred a minute on automatic machinery must be cooled on just the right cycle to evenly distribute the glass during blowing and have the bulb completed before it reaches the end of the machine.

Research on glass machinery design has enormously extended the field of glass utilization. Molded glass blocks and glass fibers of continuous or staple length are important recent products of the application of the principles of fluid flow and heat transfer to a fascinating engineering material.

Glass may be subjected to mechanical strain during its forming, and this must be removed by holding the glass at an annealing temperature for sufficient time to allow a flow of material. If plastic glass is cooled rapidly on the surface, the skin hardens before the center loses its plasticity and the surface layers are left in compression, resulting in a tempered glass. Glass has an enormous compressive strength, so that when subjected to mechanical stress it usually fails by tension opening up cracks or surface defects. Consequently, a tempered glass resists large mechanical stresses before the surface layers can be put in tension and failure ensues. The degree of temper is determined by rate of heat transfer in cooling down, and is varied with the use to which the glass is to be put. Because of the strained condition of tempered glass, cutting is impossible without fracturing the entire piece. Doors or windows must therefore be cut to size before tempering.

The opaque glasses, which are being used to such a large extent for store front, kitchen, and bathroom construction, are a tribute to engineering genius and operating skill. The crystalline components of these glasses which are responsible for their opacity and color must be controlled by furnace and forming conditions to experience the correct cooling cycle to yield exactly the right crystal size. Color is not merely dependent on correct chemical composition, but also on the thermal history, time-temperature relations, of the finished article. The effect of thermal history is also very important in the production of optical glass in controlling its density and refractive index.

In this discussion we have attempted to reflect the highlights of chemical engineering operations encountered in the glass industry. Raw materials control, combustion, heat transfer, and furnace design are so extensively important as to deserve particular emphasis. Properties of fluids and fluid flow are closely bound up with glass melting and forming operations. Mixing and briquetting are encountered in raw materials handling. Sedimentation and elutriation which enter into the classification of grinding sand used in making plate glass deserve also passing mention. We have not touched on many operations involved in pot or refractory production or raw materials purification, including mixing, filtration, controlled humidity drying, leaching and washing, because these operations are becoming more and more separate specialized industries.

Some 21,500 cars and trucks are in regular day to day service with the Bell System. The great majority have bodies specially developed by telephone engineers. Many are equipped with power winches, air compressors and pole derricks. Each of the many types is designed to handle particular functions in the construction and maintenance of telephone plant.

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G-E Campus News

"HITHER, MOUNTAIN!"

IT'S been centuries since Mahomet resigned himself to go to the mountain because the mountain wouldn't come to him. If Mahomet were living today, he wouldn't have to go to the mountain, that is, if he were at Shasta Dam—the second largest concrete dam in the world—now under construction in California.

There the world's longest conveyor belt is moving mountains—5,700,000 cubic yards of concrete and 10,400,000 tons of sand and gravel—from the processing plant to storage piles near the dam site, a distance of 9.6 miles.

Driving the conveyor belt are General Electric motors and control, thoroughly checked and tested before going on the job by young student engineers taking the G-E Test Course. J. A. Jackson, Va. Poly. Inst., '00, and R. F. Emerson, Yale, '06, had charge of the engineering at Schenectady, and A. W. Moody, U. of Calif., '36, followed engineering on the job. All three are ex-Testmen.

SUPER STREAMLINING

IN this modern age practically every means of transportation is streamlined—automobiles, airplanes, trains, and even baby carriages. The closest approach to perfect streamlining, however, is probably not found in any one of the foregoing but in a General Electric steam turbine, where nozzles must be designed to direct steam at the buckets at just the right angle.

G-E engineers have streamlined turbine nozzles to a point where they absorb less than two per cent of the velocity energy of steam traveling through turbines. Working with models, engineers about 20 years ago found they could feel low-pressure spots in an air stream blown through nozzle sections. Literally and figuratively they were "putting the finger" on streamlining deficiencies. Now, in a special laboratory, air is forced through model nozzles at a terrific speed (more than 700 miles an hour) while mechanical "fingers" feel for points of eddy or friction loss, and an automatic machine records the results.

These "streamline" tests, conducted by young student engineers "on Test" under the direction of experienced engineers, give records of inestimable value in the constant search for new ways to build more efficient turbines.

SIX VOICES

PEOPLE who have qualms about broadcasting probably would have passed right out if they had been in the shoes of George A. Mead, N. Y. State Commander of the American Legion, when he broadcasted recently from General Electric's television studios at Schenectady, N. Y.

For the first time in history a voice was carried over every practical means of voice communication. Mead's talk, in addition to going out on the ultra-short-wave band accompanying the picture on television, was simultaneously carried by WGY on long-wave radio, WGEO on short-wave, W2XOY on frequency modulation, and by light beam and ordinary telephone. In all, six distinct frequency bands carried his words to the four corners of the earth.

Directors of this unusual broadcast were John Sheehan, Union, '25, manager of G-E short-wave broadcasting, and J. G. T. Gilmour, Union, '27, program manager of G.E.'s television station, W2XB.

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